Report No. 71Y15

LEARNING PHASE FINAL REPORT

FOR THE

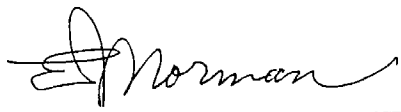
VEHICLE EMISSION INSPECTION AND

MAINTENANCE STUDY

22 January 1971

STATE OF CALIFORNIA — AIR RESOURCES BOARD

Contract No. ARB-1522



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SECTION 1
INTRODUCTION

The Vehicle Emission Inspection and Maintenance Study, as contracted by the State of California Air Resources Board, is divided into two distinct but interrelated areas of study. Part A will investigate and determine the technical and economic feasibility of instituting a mandatory program for emission testing and related corrective maintenance. Part B of the study will obtain operational data necessary to determine the respective costs and benefits of four test regimes in reducing pollutants when they are utilized in conjunction with corrective maintenance. Included in this latter pilot study is a learning phase during which a representative sample of 120 vehicles is subjected to various testing and maintenance activities. A description of the functions performed and findings relative to this initial phase of the investigation is documented. Additionally, recommended modifications that affect the subsequent test phase involving the 1200-vehicle sample are discussed.

1.1 PURPOSE

The learning phase was instituted to provide a means of familiarizing pertinent personnel with the study objectives and program implementation, to uncover and resolve unforeseen problems before proceeding with a full-scale test and maintenance program, and to establish firm testing, maintenance, administration, and management policies and procedures as they affect later phases of the investigation. Accordingly, this report identifies and documents all significant functional and operational details related to the conduct of the initial two-month effort of a 12-month study program. Furthermore, it provides the State with information that facilitates early evaluation of study progress and eliminates subsequent misinterpretation of ARB program intent and Northrop Study results.

1.2 SCOPE

Described in this report are those activities and functions related solely to the learning phase of the pilot study. This report is not, nor is it intended to be a description of any activities performed to date on Part A of the total study which investigates the feasibility of instituting a statewide program of vehicle emission inspection and maintenance. Only preliminary statistical analysis can be provided, since testing and repair in three of the four test regimes were completed 20 January 1971, and the due date of this report has been rescheduled for 22 January rather than 25 January, as previously agreed upon.

1.3 SUMMARY

The report identifies and describes the four vehicle test methodologies being evaluated. The emission test facility located at Northrop Corporation is described in terms of equipment installation and personnel. A discussion of vehicle maintenance facility selection is followed by a description of the orientation and familiarization programs instituted for the benefit of selected personnel. All facets related to the 120-vehicle sample pilot study are then fully described. Following this description, the results of the learning phase are evaluated and discussed. This report concludes with recommendations to be considered for inclusion in the 1200-vehicle test phase that would enhance the study.

1.3.1 Learning Phase Implementation

The four test regimes' functional and operational requirements were identified and analyzed to facilitate the selection of participating maintenance facilities. Based on an initial screening of qualified and interested service centers, 25 facilities were selected to participate in this pilot study. Seven centers were assigned to perform Certificate of Compliance service, and six each were assigned to accomplish Idle, Key Mode, and Diagnostic service. All of the pertinent personnel representing their respective companies were requested to attend orientation programs conducted at the emission test facility at the Northrop Corporation. This Olson Laboratory vehicle-emission test center is equipped with the following basic systems: Clayton variable inertia dynamometer, Olson-Horiba exhaust emission analysis system, Olson/PCS (Hewlett-Packard) data acquisition and control system, OLI/PCS computer-controlled driver's aid, calibration gases, Autoscan diagnostic analyzer, and the necessary exhaust and

ventilation interconnections. The installed equipments were calibrated and checked by both HEW and ARB personnel. Maintenance procedures have been firmly established for daily and weekly performance to assure high confidence in test integrity. The facility is completely staffed by qualified and experienced personnel. A specialized diagnostic training class conducted by J. DeGiorgio at the Automotive Evaluation Center at Long Beach was attended by representatives of Northrop, Olson, and the ARB.

The entire conduct of the learning phase has been dictated by the experiment design developed in conjunction with the ARB staff at Los Angeles. Stratification analysis and randomized blocking of test samples will assure that experimental errors are minimized or cancelled. Various algorithms were generated to assign vehicles to sample cells and to determine test regime scheduling. The program plan that was developed assures that the test data obtained is statistically valid.

The 120-vehicle test sample used for the learning phase was derived directly from the larger sample 1200-vehicle distribution to be processed during the main-test program. Information provided by the R.H. Donnelley Corporation as related to California vehicular registrations was used as a basis for determining the representative sample. Each selected test vehicle represents approximately 7000 registered vehicles of a given make and model year. The 1200-vehicle sample was proportionately reduced to arrive at the 120-vehicle lot on a 10:1 basis wherever possible.

To achieve a 50 percent rejection rate of all tested vehicles as dictated by the contract, for each of four test regimes, it was first necessary to test all vehicles, evaluate the results, establish the cutoff limits, and then identify those vehicles requiring corrective actions. These identified vehicles were dispatched to randomly selected maintenance facilities fitting within a given test regime-maintenance center combination.

Vehicle dispatching and queuing was controlled through the utilization of a set of three computer tab cards that identify the test vehicle, the participant, and the applicable test regime. When placed in the sectionalized card service rack located at the Test Control Office, these cards alert test and administrative

personnel of the status of each vehicle being processed. Since the 120 vehicles were selected from those volunteered by Northrop employees, vehicle pickup and delivery was limited to interfacing with the participating maintenance centers. In cases of overnight requirements, the employees were provided with one of five loan cars. Vehicle data management consisted of both manual controls and computerized data entry for later retrieval. All original data such as agreement forms, computer tab cards, emission test results, and maintenance service records, were filed in the individual folders. Relevant data required for later analysis are manually entered on computer coding forms, keypunched to computer format, and entered into the computerized data base for storage and retrieval as necessary.

1.3.2 Results and Conclusions

Twenty-seven vehicles comprised of 12 controlled and 18 uncontrolled vehicles were dispatched to seven Certificate of Compliance inspection stations for the required inspection, service, and certification. The stations were instructed to inspect and certify the vehicles in accordance with the instructions contained in the California Highway Patrol Handbook for Installation and Inspection Stations. After certification and retesting, the controlled vehicles showed an average reduction of 29 ppm of hydrocarbon (HC), 0.22 percent of carbon monoxide (CO), and 16 ppm of nitric oxide (NO_x) at an average cost of $8.22 per vehicle. Average emission reductions for uncontrolled vehicles were 100 ppm of HC, negligible amount of CO (calculated to be 0.07 percent), and 125 ppm of NO_x at an average vehicle cost of $6.02. In all cases the exceptionally high emitters were identified and corrected with favorable results.

Thirty vehicles were selected for Key Mode inspection testing. The sample was comprised of 12 controlled vehicles and 18 uncontrolled vehicles. Rejected test vehicles were sent to selected maintenance facilities along with the appropriate Key-Mode report card. Serviced vehicles were returned and retested. Unacceptable vehicles were returned for further maintenance. For the controlled vehicles, the average reduction in HC was 7 ppm and 0.72 percent in CO. However, there was an average increase of 21 ppm for NO_x. Average controlled vehicle cost was $14.91 for labor and parts. For the uncontrolled cars, the average reduction was 327 ppm in HC and 1.98 percent in CO. Similar to the controlled vehicles, however,

the average NO_x measurement increased. In these cases the average increase was 492 ppm. The average vehicle service cost was $53.47.

Thirty vehicles comprised of 13 controlled vehicles and 17 uncontrolled vehicles were selected for the Idle test regime. Failed test vehicles, of which there were 15, were sent to selected maintenance facilities along with the appropriate instruction sheets. The serviced vehicles were returned to the inspection facility and retested. For the controlled vehicles, the average reduction in HC was 166 ppm, 2.22 percent in CO, and 555 ppm in NO_x. Average controlled vehicle cost was $33.95 for labor and parts. For the uncontrolled cars, the average reduction was 545 ppm in HC and 1.94 percent in CO. The average NO_x measurement increased by 666 ppm. Average vehicle service cost was $53.84.

Thirty vehicles were selected for Diagnostic testing. The sample was comprised of 14 controlled vehicles and 16 uncontrolled vehicles. Fifteen test vehicles were rejected based on established test limits and sent to maintenance facilities for service as determined by the diagnosticians. Serviced vehicles were returned and retested. Unacceptable vehicles were returned to maintenance centers for further corrective action. For the controlled vehicles, the average reduction in HC was 49 ppm, 0.48 percent in CO, 162 ppm in NO_x. Average controlled vehicle cost was $23.65 for labor and parts. For the uncontrolled cars, the average reduction was 315 ppm in HC and 1.55 percent in CO. The average increase in NO_x was 3 ppm per vehicle. Average vehicle service cost was $64.60.

The following summarizes the direct cost of four test regimes.

Test Regime	Vehicles Serviced	Northrop Discounted Total Cost	Average Vehicle Owner Costs		
			Labor	Parts	Total
Certificate Compliance	27	$180.67	$5.83	$1.23	$7.06
Idle Test	15	$688.78	$29.90	$16.75	$46.65
Key Mode	15	$561.37	$23.39	$15.65	$39.04
Diagnostic	15	$661.27	$28.15	$18.33	$46.48

Learning phase cost analysis shows that Certificate of Compliance is by far the least costly program in view of vehicle owner expenditures. Idle testing and Diagnostic testing appear to be similar in cost and both are the most expensive as far as the vehicle owner is concerned. The report also shows that for all test regimes, except Certificate of Compliance, the controlled vehicle charges are significantly lower (40 to 70 percent) than uncontrolled vehicles undergoing the same type of test regime. The opposite holds true for Certificate of Compliance; however, the absolute magnitude of the cost differential of two dollars does not compare with the twenty to forty dollars difference experienced in the other three test regimes.

1.3.3 Recommendations and Considerations

Based on the findings and results of the learning phase, minor modifications and changes are recommended for implementation during the 1200-vehicle main test phase. These alterations will strengthen the testing activities and enhance the remaining portion of this study.

No recommendations for changes are made regarding the vehicle selection procedures as determined by the experiment design. Vehicle test scheduling will continue to be performed in accordance with the algorithms developed during the learning phase. Data handling may be modified and refined as the study progresses to increase overall information management efficiency.

For the Certificate of Compliance test regime, it is recommended that basic idle adjustment of speed, carburetor, and ignition timing to manufacturer's specifications be made on all uncontrolled vehicles. This should result in greatly reduced emissions with nominal cost increase. No changes are recommended for the Idle test procedure as used during the learning phase. Regarding the Key Mode test procedures, the Clayton Manufacturing Company recommends that a Full Throttle test be included to supplement the three primary modes of idle, low cruise, and high cruise. However, they suggest that data derived from this test be used only for analytical purposes and thus repairs will not be dictated based solely on the full throttle test results. There are certain risk factors to be considered before this test is implemented. Northrop is agreeable to incorporating this recommendation. However, this would constitute a change in scope requiring approval by and

negotiations with the ARB. The Diagnostic test procedures used during the learning phase will basically remain as used. However, more emphasis will be placed on using emission data to determine specific repair action as relatable to a failure mode of the test cycle. Refinements in the present procedures will be pursued during the course of the study.

Current procedures call for retest of only those cars requiring maintenance service. For the 1200-vehicle test phase, it is recommended that a control group of 50 cars which pass their respective tests and receive no service undergo a second seven-mode test at some agreed upon interval to determine and establish total inspection system (hardware, software, personnel, and procedures) test reliability and repeatability. As presently configured, the retest scheduling does not assure that emission changes were indeed the result of maintenance and service performed.

Minor modifications to the emission limits used during the learning phase are proposed for the main 1200-vehicle test. There were no limits established for the Certificate of Compliance and this will remain in effect for the remainder of the test phase. Changes recommended for the Idle test limits are increases from 250 to 300 ppm for HC on controlled cars and from 5.0 to 6.0 percent CO for uncontrolled cars. For the Key Mode test, it is recommended that the carbon monoxide limit at low cruise for uncontrolled vehicles be raised from 3.5 to 4.5 percent as proposed by Clayton Manufacturing Company. The recommendation is based on a careful analysis of test data by all concerned parties. For the Diagnostic test regime, it is recommended that no single value or limit for carbon monoxide be used for rejection purposes during the full-throttle 60 mph mode.

To increase communication and information exchange between the Test Control office and the participating maintenance facilities, two avenues will be pursued. First, a memorandum will be supplied to each facility to restate the purchase order requirement that removed parts be returned to Northrop. Secondly, revised data sheets will accompany each vehicle to be serviced and must be returned with the vehicle after service.

SECTION 2
TEST REGIMES DEFINITION

Four test methodologies or regimes are being considered and evaluated during this study. These test regimes are the Certificate of Compliance, Idle, Key Mode, and the Diagnostic inspection procedures. In the following paragraphs, each of these are briefly described. Further detailed discussions on inspection procedures are presented in Section 7 of this report.

2.1 CERTIFICATE OF COMPLIANCE TEST REGIME

In accordance with the requirements of Chapter 4, part 1, Division 26 of the Health and Safety Code and the rules and regulations of the Air Resources Board[1], a Certificate of Compliance is issued to indicate that the identified vehicle is properly equipped with the motor vehicle pollution control device(s) required by law. Primarily, the certification is obtained and required during transfer of ownership as directed by the Vehicle Code. However, the certificate may be requested and issued anytime proof of compliance is desired. Briefly, the Certificate of Compliance inspection and servicing procedure involves the following sequence of operations. A more detailed procedure appears in the reference document and elsewhere in this report.

2.1.1 Crankcase Devices

As extracted from the California Highway Patrol document, the following is presented as a synopsis of events for cursory information purposes only.

a. Identify and confirm that the vehicle has an approved device installed.

[1] Handbook for Installation and Inspection Stations, Department of California Highway Patrol, August 1969, page 3-9

b. Test the device for satisfactory operation with engine warm and running at idle condition.

c. Clean, service, or replace device in case of unsatisfactory operation. Use the manufacturer's recommended instructions.

2.1.2 Exhaust Emission Control Systems

To continue meeting California emission standards, the necessary maintenance and adjustments must be accomplished according to manufacturer's recommendations and specifications. In effect, the control system inspection involves checking those items and adjustments of an engine which affect exhaust emissions. The procedures are summarized below.

a. Visually check all installation connections to air pump, hoses, valves, and air distribution manifolds while engine is stopped.

b. With engine at normal operating temperature, check and/or adjust ignition timing, idle mixture, and idle speed.

2.2 IDLE INSPECTION TEST REGIME

The present Federal standard testing procedure for auto exhaust emissions consists of seven modes of operation: two accelerations, two cruises, two decelerations, and idle. These seven modes are cycled four times around from a cold start through warm-up, then two more times as a hot start, or completely warmed-up car. The standard test of seven modes requires loading of the engine. An alternative method suggests that omission of some of the modes and reduction of the number of cycles may be as effective in identifying high emitters. The idle mode has been shown to be the best single mode for this purpose.[1]

[1] Chew, Marian F., "Auto Smog Inspection at Idle Only", Society of Automotive Engineers, Mid-Year Meeting at Chicago, Ill, May 1969, Paper 690505

In this test regime, the vehicle is operated until proper engine temperature is achieved, the emission sampling and analysis equipments are operated, and the results are obtained. Unacceptable vehicles are then dispatched to maintenance facilities.

2.3 KEY MODE INSPECTION TEST REGIME

Analysis has been conducted to determine the minimum number and variety of vehicle operating modes necessary to reveal engine malfunctions attributable to unnecessarily high emissions. The work involved both controlled and uncontrolled vehicles representative of domestic engine types, displacements, carburetion, and transmission options. The operating modes that most reliably identified engine faults were labeled "Key" modes.[1] These modes have been named high cruise, low cruise, and idle. For each of these modes, failure levels are established for HC and CO concentrations and corresponding probable engine malfunctions are denoted. Suspect vehicles are then sent to participating garages for repairs indicated by the Key Mode inspection.

2.4 DIAGNOSTIC INSPECTION TEST REGIME

The Diagnostic inspection technique requires operating the test vehicle on a chassis dynamometer to simulate driving and road conditions. The steady-state modes of operation are idle, full-throttle at 60 mph, and cruise at 50 mph, and a transient deceleration mode. During each of the operating modes, the exhaust is analyzed for concentrations of hydrocarbon; oxides of nitrogen concentrations are measured only during the cruise mode; and carbon monoxide is measured in all modes except deceleration. Vehicles failing established limits are diagnosed using the oscilloscope console, after which they are driven to the maintenance facilities for corrective action.

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[1] Cline, E. L., "A Realistic Vehicle Emission Inspection System", Clayton Manufacturing Company, El Monte, California, APCA Paper 68-152

SECTION 3
EXPERIMENT DESIGN CONSIDERATIONS

The current effort involves the experimental evaluation of four candidate emissions test and reduction schemes. A fundamental feature of any experiment is a statistically sound experimental design. To avoid wasted data-taking, insufficient data collection, or inconclusive results, the experimental design must be configured prior to performing the experiment itself. The purpose of an experimental design is to control random errors and bias so that any conclusions based upon the obtained data are sound, consistent, and repeatable. A requirement in determining the procedures to be used during the learning phase, and subsequently throughout the main test phase of the current program, is a comprehensive experimental design. The design adopted for use in the learning phase and recommended for implementation in the main test phase is described in the following paragraphs.

3.1 STRATIFICATION ANALYSIS AND RANDOMIZED BLOCKING

A randomized block plan was utilized as the basic experimental design in the study. Random blocking, properly designed, assures that a representative sample of test subjects is exposed to each test, and at the same time, assures that the selection of each subject to be exposed to a given test is purely random. The block design is structured so that experimental errors will tend to cancel one another internally.

The experiment also must comply with the realities of the available data. Only the age, make, and model of a car are known before it may become a test subject. Because of cost, time involved, and the inability to reproduce original operating conditions, each car may be exposed to only one combination of test type and repair station.

To satisfy the basic purpose of the test, the measurement of reduction of emission level, the principal random variable was selected as Z, where:

$Z = \alpha - B$

α = gpm output of a contaminant produced by a sample of vehicles prior to servicing

B = gpm output of a contaminant produced by the same vehicles after servicing

3.2 HYPOTHESES TESTING

The purpose of the experiment is to compare the relative merits of the four test regimes:

a. Certificate of Compliance
b. Idle
c. Key Mode
d. Diagnostic

In statistical terminology, we wish to test the hypotheses:

First level H_1: $\alpha_1 = B_1$ (total population)

H_2: $\alpha_2 = B_2$ (each test, each pollutant)

H_3: $Z_A = Z_B = Z_C = Z_D$ (for test types a, b, c, d above)

The hypotheses are that there is no difference between test results on the vehicle population before and after service, and that there is no difference in results by test types. Very likely, there will be differences, and the experimental design will identify and quantify them.

The testing pattern chosen was structured to pass an equal number of cars through each test and maintenance station type. The structure assures that a representative cross-section of the vehicle population (based on age, make, and model) is

exposed to each type of test and repair facility. Importantly, the matching of individual cars to test and maintenance station types is purely random.

3.3 VEHICLE SAMPLE ASSUMPTIONS

Assumptions concerning the vehicle sample which are implicit in subsequent analyses are:

a. The 1200 selected autos form a representative cross-section (based on the classifications, age, make, and model) of the passenger-vehicle population of California.

b. Cars selected are drawn from a normal (or other standard frequency distribution) population of cars of that age, make, and model.

3.4 DESIGN CRITERIA

The criteria selected as important to the experimental design were:

a. That an equal number of cars be exposed to each test type.

b. That the sample population be blocked so that each test type will receive an equally representative sample of cars based on age, make, and model of test subjects.

c. That the test be internally structured to minimize the effects of random error, learning curves, instrument drift, and other such time-dependent errors.

d. That randomization be used at every level of assignment within the structure.

3.5 TEST VEHICLE ASSIGNMENT ALGORITHM

Table 3-1 identifies the test variables under observation during this experiment.

Table 3-1. Identification of Test Variables Under Observation

Variable Identification	Variable	Classification
I	Exhaust controls	Controlled or uncontrolled
II	Age	Year
III	Size	Foreign, compact, specialty, medium, station wagon, large
IV	Emission test type	Certificate of Compliance, Idle, Key Mode, Diagnostic
V	Time	Four quarters

The algorithm chosen for assignment of vehicles to a given cell of the block matrix incorporates all of the criteria outlined in paragraph 3.4. Initially, the vehicle sample is divided into two groups: one composed of uncontrolled vehicles and the other composed of controlled vehicles. The following steps are then applied to each of the two groups independently to obtain randomized assignments of each vehicle in the test sample.

(1) Cars in both the controlled and uncontrolled groups are sorted separately by size.

(2) Within each size grouping, cars are ordered by year.

(3) Groups formed by steps (1) and (2) above form six groups within the controlled group and six groups within the uncontrolled group that are each ordered by model year.

(4) Cars of the same size and age are randomly distributed by make within each of the twelve age-size blocks.

(5) The sample, as it is ordered by the above scheme, is further divided into successive subgroups of 48 cars each.

(6) Cars in each of these subgroups are randomly assigned to each of the four emission tests.

(7) The twelve cars in each subgroup, that are assigned to a given test, are assigned randomly and by proportion to the three types of maintenance centers in the maintenance center group assigned to that test.

(8) The same twelve cars are divided into four groups of three cars each. Each group of three is assigned randomly to one quarter of the testing period.

This assignment algorithm, executed prior to the commencement of testing, assures orderly, accurate vehicle scheduling and experiment design validity and control.

3.6 VEHICLE TEST SCHEDULING ALGORITHM

It is next important to consider scheduling details of the actual laboratory test rather than selection and assignment of the test subjects. It is important to account for variability of personnel performance throughout the course of testing, personnel learning curves, instrumentation variation, and similar time-dependent phenomena. A procedure often used in statistics to account for such effects is one which assures testing of all possible combinations of variable types in a random order. This procedure of recombination is called Latin Squares. The important characteristic of the Latin Square is that no variable appear twice in the same row or column.

Four possible 4 x 4 Latin Squares are:

ABCD	ABCD	ABCD	ABCD
BADC	BCDA	BDAC	BADC
CDBA	CDAB	CADB	CDAB
DCAB	DABC	DCBA	DCBA

The columns represent a test type, the variable names represent a repair station type, and the rows represent a four-day test sequence. The algorithm developed proceeds as follows:

(1) Randomly match one of the Latin Squares to a testing period quarter.

For each quarter,

(2) Randomly match the column headings to:

a. Certificate of Compliance
b. Idle
c. Key Mode
d. Diagnostic

(3) Randomly reorder the rows

ABCD

(4) Randomly reorder the columns

A
B
C
D

(5) Randomly match A, B, C to garages, service stations and dealers. If D appears, randomly select A, B, or C.

(6) Then follow the basic pattern:

1st sequence	M	T	W	Th	M = Monday
2nd sequence	F	M	T	W	T = Tuesday
3rd sequence	Th	F	M	Tu	W = Wednesday
4th sequence	W	Th	F	M	Th = Thursday
					F = Friday

superimposed on the Latin Square.

(7) For a given day, the cars that are tested are those that belong to the assignments which match the column heading (test type) and have the service type appearing in the corresponding row and column of Latin Square matrix.

This pattern assures that the test types and repair types are rotated throughout the week so that the same test type isn't twice performed on the same day of the week in any two successive weeks within a given test period. Neither is the order of performing the test types within a given quarter of the test phase repeated. Service assignments are also controlled. However, the matching of individual tests and repair facilities, and test sequence selection are random.

3.7 AREAS OF IMPROVEMENT

A vital part of any experiment is the isolation and quantification of the variables under observation. The above design fulfills these requirements in all but one extremely important area. No method is provided to separate the emission reduction achieved due to maintenance performed by garages from statistical fluctuations in equipment and personnel performance. In essence, the experiment outlined above has no control group. If as few as 30 cars which passed their respective tests were subjected to a second subsequent 7-mode test, they would form a valid control group, and the precision of the results obtained would be known. Without such a control group, there is no way of knowing whether measured reductions are real or simply artifacts of the testing system, which includes such unknowns as personnel performance and equipment reliability. Using well-known statistical techniques such as a two-tail test applied to a Student-T distribution, the consistency of results may be assured.

It might be argued that since it is the relative effectiveness of the four test regimes that is being evaluated, the effects described above will apply equally to all tests, and that therefore, no control group is required. This argument ignores the possibility that system error may be significant enough so that the true emission reductions obtained will be far below that calculated directly from measurement equipment. More importantly, if such effects are not accounted for, there can be

no analytical prediction of the overall emission-reduction effectiveness of any recommended program.

The recommended improvement is a structured experiment to be performed on, at most, 50 "passing" vehicles. The experiment will segregate self-repeatability (the deviation between results of two tests performed on the same car by the same driver) and personnel consistency (deviations between tests performed on the same car by different drivers). With the implementation of this recommended change, the test plan and test operations themselves will provide a framework in which statistically valid data may be gathered and analyzed.

SECTION 4

OLSON LABORATORY (OLI) VEHICLE EMISSION INSPECTION

The vehicle emission inspection and analysis facility, located at Northrop Corporation, is described in terms of equipment and personnel. Equipment calibration and checkout are described along with correlation with ARB equipment.

4.1 EQUIPMENT SELECTION AND INSTALLATION

The OLI Vehicle Emission Test Center has been equipped with the following:

- Clayton variable inertia dynamometer (dyno) with 250-pound increment inertia loading weights. The dyno has been specially prepared by the Clayton Manufacturing Company to allow wide open throttle (W.O.T.) runs at 60 mph.

- Olson-Horiba exhaust emission analysis system equipped with model AIA NDIR analyzers. The analyzers have the following full scale ranges:

Carbon monoxide	0 - 10%
Carbon dioxide	0 - 15%
Low hydrocarbon	0 - 0.1% (n-hexane)
High hydrocarbon	0 - 1% (n-hexane)
Nitric oxide	0 - 0.1/0.4%

The system includes three dual-pen Honeywell recorders for continuous dynamic measurement and a computer interface bench-operator's console including a digital voltmeter to measure voltage outputs of the NDIR analyzers.

- OLI/PCS (Hewlett-Packard) data acquisition and control system with data readouts on volumetric, mass equivalent and on a mode-by-mode basis.

- OLI/PCS computer-controlled drivers aid for seven-mode, and key-mode testing.

- OLI calibration gases analyzed to $\pm$ 2%.

- Autoscan model 4000 diagnostic analyzer.

- Hartzell portable fan providing 5300 cfm.

- Exhaust blower installation for removing tailpipe exhaust.

A permanent fixed-base facility has been constructed, with the dynamometer sunk into the floor to provide a flush mount installation. Separate electrical circuits have been installed for the various pieces of equipment to eliminate voltage fluctuations due to the different load demands. A blower with the necessary ducting has been installed to exhaust the tailpipe gases. In addition, an overhead exhaust system is used to keep the general operational area free from exhaust or evaporative emissions. This ambient condition has been monitored and found to be at a safe level.

4.2 EQUIPMENT CALIBRATION AND CHECKOUT

To provide quality assurance on all equipment, data processing hardware, software, calibration gases, and test procedures, the OLI analytical system and computer underwent extensive correlation tests prior to installation in the present facility. It was cross-checked against a system having Beckman Model 315-A analyzers plus its own OLI/PCS data processor. Three simultaneous cold-start emission tests were conducted under the direction of the HEW project officer from the Department of Motor Vehicle Pollution Control. Further confidence level was acquired by additional correlation between the ARB and OLI analytical systems. This procedure was separated into four parts, each of which is explained below:

a. Instrument Curve Generation - Analyzer curves were generated for each system independently. The infrared analyzers of the OLI system were

calibrated with OLI calibration gases, and the ARB performed calibration with their own gases. This will provide a cross-check between standard gases during part B.

b. Calibration Gas Norming - The ARB Mobile Laboratory was driven to the Northrop/Olson Test Facility. Using OLI calibration gases (black standards), each system was used to rename the gases for a static correlation. This also gave a good cross-check between the daily working gases. A minimum of three bases were used on each of the LHC, HHC, CO, CO_2 and NO infrared analyzers of both the ARB and OLI analytical systems.

c. Steady-State Tests - Simultaneous steady-state emission tests were conducted by the ARB and OLI systems. This was accomplished by inserting the sample probes of both analytical systems into the same tailpipe of a vehicle. Two vehicles were used: a 1964 Cheverolet supplied by the ARB, and a 1970 Ford supplied by OLI. The steady-state modes consisted of cruises at 50, 30 and 15 mph, plus an idle mode.

d. Hot-Start Tests - To investigate modal values on a dynamic basis, four seven-mode tests were conducted on each of three different vehicles. These simultaneous tests provided final correlation between the two systems.

The Air Resources Board at Los Angeles has all OLI strip-charts and computer print-outs in its possession and is currently evaluating the data. Results are reported to show good correlation on the cross-check with the calibration gases.

4.3 INSPECTION EQUIPMENT MAINTENANCE

Maintenance and calibration inspection is continually required to perform precise exhaust emission measurements. To assure and maintain this quality, OLI has instituted several daily and weekly procedures which are outlined below.

4.3.1 Daily Procedure

a. Check chart paper, recorder ink supply and event markers.

b. Check sample line connection location at sample/tailpipe purge selector valve for leaks. Leak-check entire system.

c. Check recorder and computer zeros.

d. Flow zero and span gases through the system and check specified gain with the digital voltmeter (DVM).

e. Check 100 percent CO_2 response on the LHC instrument.

4.3.2 Weekly Procedure

a. Inspect the probe and sample line for contaminants and replace if necessary.

b. Inspect the system for clean plumbing and replace contaminated lines.

c. Periodically flush the condensation coils and traps with trichlorethylene followed by soapy, then clean water.

d. Check all sampling legs for maximum flow.

e. Sampled handling components in the dia-pumps should be cleaned periodically and the diaphragms replaced.

f. Check maximum instrument tune and reset.

g. Service all strip-chart recorders per the manufacturer's instructions.

h. Service the dynamometer per the manufacturer's instructions.

i. Hand read strip-charts and compare raw values and computer printout. Apparent problem areas are investigated immediately.

4.4 INSPECTION FACILITY PERSONNEL

Presented below are brief resumes of the technical personnel staffing the inspection facility.

- Mr. J. Vance is the Test Supervisor of the inspection team. He has had five years of experience in various emission testing programs and holds an Associate Degree from San Bernardino Valley College. He recently underwent a 40-hour diagnostic course to prepare himself for the "diagnostic emission test" of the program.

- Mr. R. Morris is the Systems Operator and has had past experience in this area. He has attended a 40-hour diagnostic course.

- Mr. J. Buxton handles the quality audit procedures and maintains equipment proficiency. Mr. Buxton has 10 years experience in the automotive emissions field and has attended San Bernardino Valley College.

- Miss A. Forker, Data Analyst, has been responsible for OLI's strip-chart reading and data reduction for the past year. She holds an Associate Degree from San Bernardino Valley College.

- Mr. A. Toy, Test Driver, has been trained to drive the different emission test cycles and the associated procedures. Mr. Toy has been involved with the program since the beginning of the learning phase.

SECTION 5
VEHICLE MAINTENANCE FACILITY SELECTION

The design goal in the selection of vehicle maintenance centers has been to attain a complement of automotive maintenance and service facilities that approximates the mix of automobile dealerships, independently owned and operated garages, and service stations found in the State, on condition that all selected facilities be licensed "Class A" garages as defined by the California Highway Patrol.

5.1 FACILITY REQUIREMENTS AND QUALIFICATIONS

All candidate maintenance facilities fulfilling the Class A license requirement should also be situated within a reasonable distance of the testing facility to minimize transit time between test and repair sites. In addition to the obvious cost savings, such a plan would allow program personnel to more easily inspect, whenever necessary, a given vehicle undergoing maintenance. It might well be argued that such geographical biasing decreases the representativeness of the maintenance-center sample finally selected. To appreciate the minor detraction imposed by this requirement, it is necessary to understand in what sense the sample is intended to be representative.

Clearly, one would not expect any sample of 25 maintenance centers, selected at random from the many thousands of dealerships, service station, and garages in the State to be truly representative of a mechanic population whose capabilities and qualifications have never been adequately assessed. If what is sought is representative cost, this is to some extent assured by the standardized labor charges delineated in the Motors Flat-Rate and related manuals. If it is expected that the garage personnel will service test-cars with the same care exercised in their repair of cars owned by the general public, this must also be discounted since all participating maintenance personnel were required to be oriented and informed of the intent of the current program.

Although great care was taken to obtain the largest possible number of maintenance centers for each of the test/repair modes under evaluation, there are no statistically valid means of assuring that the complement of facilities selected represents anything other than the proportion of dealers, garages, and service stations present in the maintenance-center population of the State.

Bearing these factors in mind, a total of 27 maintenance centers were identified, initially, as potential participants. Willingness of facility personnel to participate in the program was also a determining selection criterion.

The finalized list of maintenance participants consists of three groups of six centers each for the Idle, Key Mode, and Diagnostic tests, and one group of seven centers for the Certificate of Compliance test. (The additional maintenance center is required for the Certificate of Compliance group because of the many differing emission devices designed by the major automobile manufacturers.) To eliminate any biases introduced by division of centers by test type, it was suggested that the various test types be rotated periodically among the four groups of maintenance facilities to expose each emissions test and maintenance scheme to all participating facilities. The Air Resources Board determined that such rotation was not necessary. It is assumed that 50 percent of automotive repair work in the State is performed by authorized automobile dealers, 33 percent by independent garages, and that 17 percent is performed by service stations. The structure of each group of repair facilities reflects this assumption. In addition, each group contains some garages which are members and others which are nonmembers of the Independent Garage Owners Association.

5.2 SELECTED VEHICLE MAINTENANCE CENTERS

The individual service centers were selected randomly for each group according to the criteria and structure delineated above. The maintenance centers selected are as follows:

Test A - Certificate of Compliance (All approved smog control stations)

Jerry Goodwin Dodge, Inc., Fullerton
Gaudin Ford, Buena Park
Casey-Beckham Pontiac, Anaheim
Bob Jones Toyota, Fullerton

Cotton Goff VW, Buena Park

Al's Auto Electric (IGO), Anaheim

Dale Jones Mobil, Fullerton

Test B - Idle Test

The following six facilities have been issued ARB Idle test equipment as noted.

Cone Chevrolet, Fullerton (State of Calif. S/N 1061)

McCoy & Mills Ford, Fullerton (State of Calif. S/N 1062)

Bryant Pontiac, Covina (State of Calif. S/N 1063)

Neuman Carburetor & Diagnostic, Anaheim (State of Calif. S/N 1064)

555 Automotive Center (IGO), Stanton (State of Calif. S/N 1066)

College Shell, Fullerton (State of Calif. S/N 1065)

Test C - Key Mode Test

McCoy Ford, Anaheim

Steffy Buick, Anaheim

Ballard Motors VW, Anaheim

Leo's Automotive, Fullerton

Freek's Auto Service (IGO), Fullerton

Bob's Standard, Garden Grove

Test D - Diagnostic Test

Sierra Lincoln-Mercury, Fullerton

Hansel Olds, Inc., Fullerton

Anaheim Dodge, Anaheim

United Automotive, Santa Ana

J. C. Penney, Fullerton

Bill Hyland's Union Service, Anaheim

SECTION 6
ORIENTATION AND FAMILIARIZATION PROGRAMS

Two types of orientation and familiarization programs were instituted to inform and train the affected personnel. Orientation sessions were held for the benefit of maintenance facility personnel, and a training class was conducted for diagnosticians.

6.1 SELECTED MAINTENANCE PERSONNEL

An orientation session was conducted for service managers and mechanics of one of the four groups of participating maintenance centers on each night from December 1 through December 4, 1970 at the Northrop testing facility. Program personnel provided an introduction to the aim and scope of the current effort, and explained the role of each of the maintenance centers. The tentative procedures for the appropriate test type were distributed and discussed. Each session lasted 2 to 3 hours and included a tour of the test area and an explanation of test-site testing procedures and methods.

6.2 TRAINING OF DIAGNOSTIC PERSONNEL

The prescribed training program for personnel assigned to perform the Diagnostic test was conducted at the Joe DeGiorgio Automotive Evaluation Center in Long Beach, the week of November 17, 1970. The program consisted of five 8-hour sessions of lecture, demonstration, individual and group participation in the theory and practice of automotive engine diagnosis, exhaust emission diagnosis, and in the appropriate methods for emission reduction. The training provided participating program personnel with the ability to identify causes of excessive emissions through the analysis of major automotive engine systems. The specific causes were incorrect adjustments, part deficiencies, or some combination of the two. Attendees included representatives from Northrop Corporation, Olson Laboratories, and the Air Resources Board.

SECTION 7
120-VEHICLE SAMPLE PILOT STUDY

In the previous sections, the various test regimes being considered for evaluation have been discussed. The emission analysis test facility also has been described. Considerations leading to the development and implementation of the learning phase have been discussed as part of the experiment design. In the following paragraphs, detailed information is presented to describe the task of selecting the 120-vehicle sample lot, the controlling and scheduling of test vehicles, the orderly dispatching and queuing of participating vehicles, and the approach pursued to assure total data management. Emission test data analysis is followed by a discussion on establishing test regime emission limits. The results of post-maintenance activities are presented in terms of changes in emission levels, vehicle maintenance performed, and direct costs incurred to achieve the emission changes.

7.1 TEST VEHICLE IDENTIFICATION AND ACQUISITION

The aim of the test-vehicle selection procedure was to provide two representative random samples of privately-owned automobiles under 6001 pounds gross weight, currently in use in California. One hundred-twenty vehicles form the learning phase sample; an additional 1200 vehicles comprise the main test sample. Since the learning-phase sample is derived directly from the test-phase sample, the latter is discussed first.

7.1.1 Vehicle Population Representative Sample

The 1200-car sample presented in Table 7-1 is representative of the current statewide population of privately-owned passenger automobiles fulfilling the conditions stated above. The selection is based upon registration data provided by Reuben H. Donnelley Corporation that included the current California registration figures for April 1970 and new-car registrations for January through July 1970. These sources

Table 7-1. 1200-Vehicle Sample

MAKE - MODEL	70	69	68	67	66	65	64	63	62	61	60-57	PRD *	ACT **
BUICK	2	3	3	3	3	3	3	2	2	2	9	46	36
Special	1	2	2	2	2	3	3	2	2	1	-	20	20
CADILLAC	2	3	3	3	3	3	3	3	3	2	7	34	35
CHEVROLET	7	8	8	10	13	16	15	13	11	8	44	148	153
Chevelle	4	4	4	4	5	5	4	-	-	-	-	30	30
Corvair	-	-	-	-	1	2	2	3	3	3	2	16	16
Chevy II	3	3	2	1	2	2	3	5	4	-	-	24	25
Camaro	2	4	3	4	-	-	-	-	-	-	-	12	13
CHRYSLER	1	2	2	2	3	2	2	2	1	-	3	19	20
DODGE	3	4	5	3	4	3	3	2	2	1	5	34	35
Dart	2	2	2	2	2	3	3	3	1	1	-	20	21
FORD	7	7	7	7	8	8	8	7	6	5	27	93	97
Falcon	1	1	1	2	2	2	3	3	4	5	4	27	28
Fairlane	2	2	3	2	2	2	2	3	2	-	-	20	20
T-Bird	1	1	1	1	1	1	2	2	2	1	1	14	14
Mustang	4	5	5	8	10	12	-	-	-	-	-	42	44
IMPERIAL	-	-	1	-	-	1	-	-	1	-	-	3	3
LINCOLN	-	1	1	1	1	1	1	1	1	1	1	9	10
MERCURY	1	2	1	1	2	2	1	1	1	1	4	17	17
Comet	1	1	1	1	1	1	2	2	3	2	1	15	16
Cougar	1	2	2	3	-	-	-	-	-	-	-	8	8
OLDSMOBILE	2	3	2	2	3	3	3	3	3	2	8	33	34
F-85	2	2	3	3	2	2	2	2	1	1	-	20	20
PLYMOUTH	4	4	4	3	3	3	2	2	1	1	10	36	37
Valiant	1	1	2	2	2	3	3	2	1	1	1	18	19
PONTIAC	2	3	3	3	4	4	5	4	3	2	8	40	41
Tempest	2	3	3	4	4	3	3	1	2	1	-	24	26
Firebird	1	1	2	2	-	-	-	-	-	-	-	5	6
AMERICAN MOTORS	2	2	3	2	2	4	6	6	5	3	6	39	41
OTHER DOMESTIC	-	-	-	-	1	-	1	1	1	1	8	13	13
IMPORT P/C-7	-	-	-	-	-	-	-	-	-	-	-	34	-
VOLKSWAGEN	14	13	12	9	9	9	7	6	5	4	13	91	101
STATION WAGONS	13	17	13	11	12	13	14	13	11	8	28	152	153
P/C-6 *													
Toyota	11	10	4	4	2	-	-	-	-	-	-		31
Datsun	6	5	3	2	1	-	-	-	-	-	-		17
TOTALS	105	121	111	107	110	116	106	95	82	57	190	1202	1200

* Number Predicted By Strict Proportion
** Number in Test Sample

were combined to provide an accurately stratified random sample designed for implementation on September 10, 1970, as originally provided for by the Request for Proposal. It is doubtful that the three-month delay in the State's authorization to proceed significantly affects the representativeness of the proposed sample, particularly since it was previously determined that 1971 model automobiles would not be included.

R.H. Donnelley's figures were used to project total auto sales for 1970. This projection was accomplished by multiplying the accumulated percentage change in the number of registrations for each make from 1969 through July 1970, by the 1969 sales figures. The percentage change for each make was applied uniformly over all models within that make. Attempts were made to obtain current sales for each model from the various automobile manufacturers. In each case, the manufacturers' tabulations by model were incomplete to the extent that they proved to be of little or no use. The resulting distribution is based on a population of approximately 8-1/2 million elements (vehicles), each sample vehicle representing approximately 7000 registered vehicles. For the 1200-vehicle test sample, strict proportion was adhered to in all but two cases: imported cars and Chrysler Imperials.

7.1.1.1 Imported Cars

The imported-car portion of the total vehicle population other than Volkswagen is completely described by the two vehicle classes, P/C-6 and P/C-7. The criterion for assigning a given import to one of these classes is its manufacturer's suggested retail base price. Imports having a base price lower than $3500 are assigned to P/C-6. Those with a higher base price are assigned to P/C-7. The makes of cars comprising class P/C-7 are listed in Table 7-2.

In the case of class P/C-6, strict proportion would distribute 57 cars over more than twenty makes which include Volkswagen (VW). Approximately 40 percent of the late-model foreign-car market in California[1] is represented by VW. The second and third best-selling P/C-6 cars in 1970 represent a vast majority of all other cars sold within this category. Consequently, in addition to VW, the entire class of P/C-6 is

[1]Motor Registration News published by Reuben H. Donnelley, Aug. 1970.

Table 7-2. Imported Cars in Class P/C-7

Alfa Romeo	Mercedes
Arnault Bristol	Maserati
Aston Martin	Moretti
Austin Healey	Morgan
Bentley	Porsche
BMW	Rolls-Royce
Citroen	Rover
Ferrari	Singer
Humber	Triumph
Jaguar	Volvo
Lancia	

represented in the 1200-car sample by those other two makes, Toyota and Datsun. Neither of these makes was sold in any significant quantity in American prior to 1965 therefore, since no make other than Volkswagen represents a significant portion of the foreign-car population prior to that year, class P/C-6 for model years 1957-1965 is represented solely by Volkswagen.

In the case of class P/C-7, a survey of current registration figures and of the car makes of which that class is comprised indicates that strict proportion would distribute only three percent of the total sample over twenty-one different makes, each representing an insignificant portion of the total vehicle population of the State. At the same time, each such make involves highly individualized maintenance requirements. For these reasons, class P/C-7 was eliminated from the sample, and its requisite number of cars was distributed proportionally among the major makes of domestic cars of comparable size.

7.1.1.2 Chrysler Imperials

Registration figures would require that a total of three Imperials be present in a strictly proportional representation. However, there is no single model year for which Imperial registration figures are sufficiently large (at least 7000) to warrant the inclusion of Imperial in the 1200-vehicle sample. Consequently, one Imperial was selected for each of three model years assumed representative.

7.1.2 Learning-Phase Sample Selection

After completion and verification of the test-phase sample, the learning-phase sample was drawn directly therefrom by strict proportion wherever possible. In categories where insufficiently large numbers in the test sample precluded selection of a vehicle of a particular make, model, and model-year for the learning-phase sample, two or three model years were grouped together to allow inclusion of a car of the given make and model. A listing of the 120 vehicles tested in the learning phase is presented in Table 7-3.

7.2 VEHICLE SCHEDULING, DISPATCHING, AND DATA MANAGEMENT

To achieve a program goal of 50 percent rejection of the 120 test vehicles based on exhaust emission analysis, it was necessary to first schedule and complete all of the base-line 7-mode testing and the emission tests for Idle, Key Mode, and Diagnostic tests. Firm pass/fail limits could then be established from the data. The failed vehicles were identified and then rescheduled for service and subsequent retesting.

These pass/fail limits determined in the learning phase will be used and refined during the main test program. Unlike the learning phase, test vehicles will be dispatched for any required service immediately after the initial test. Retesting will be performed upon return from servicing. The cars will not be returned to their owners until emission concentrations are reduced to a satisfactory level, generally within two days. The only rescheduling necessary, therefore, is that performed at the six-month interval after the initial testing is completed to evaluate the deteriorating effects of time and mileage.

Data obtained in the learning phase was logged on computer coding sheets in tabular form so that manual data reduction could be accomplished and keypunched easily for ultimate storage in the computer data base that will be formed during the main testing program.

File folders for each car tested contain all original information regarding the car including acceptance form, loan agreement, IBM routing cards, test results, and repair invoices.

Table 7-3. 120-Vehicle Learning-Phase Sample

MAKE - MODEL	70	69	68	67	66	65	64	63	62	61	60-57	TOTAL
BUICK		1									2	3
Special	1		1			1	1	1				5
CADILLAC				1	1				1			3
CHEVROLET	1	1	1	1	1	2	2	1	1	2	5	17
Chevelle		1		1			1					3
Corvair						1	1					2
Chevy II										1		1
Camaro		1					1	1				3
CHRYSLER		1	1					1				3
DODGE		1	1								1	3
Dart						1		1	1			3
FORD	1		1	1	2	1	1	1			4	12
Falcon		1					1					2
Fairlane							1					1
T-Bird							1					1
Mustang	1		1	1	1	2						6
IMPERIAL												-
LINCOLN					1							1
MERCURY					1	1	1					3
Comet					1				1			2
Cougar			1									1
OLDSMOBILE					1		1	1				3
F-85		1	1				1	1	1			5
PLYMOUTH	1				1		1				1	4
Valiant			1					1				2
PONTIAC		1		1	1	1	1	1		1	1	8
Tempest					1	1						2
Firebird		1										1
AMERICAN MOTORS				1			1				1	3
OTHER DOMESTIC						1						1
IMPORT P/C-7												-
VOLKSWAGEN	1	2	1	1	1		2	1	1		1	11
P/C-6	1		1									2
Toyota			1									1
Datsun	1	1										2
TOTALS	8	13	12	8	13	12	18	11	5	4	16	120

7.2.1 Vehicle Scheduling

The vehicles identified in the sample (para. 7.1.2) were randomly assigned in equal proportions to the four test types being evaluated. All cars for the baseline 7-mode hot-start test and the appropriate emission test were initially scheduled at the rates shown in Table 7-4. The tests were actually accomplished as shown in Figure 7-1.

7.2.1.1 Certificate of Compliance

Service was begun on December 17 at the rate of ten per day. Three of the thirty cars to be serviced had no emission control devices and the owners of three other cars were not available. Twenty-four cars were serviced and given a final 7-mode test by December 21. One of the earlier nonavailable cars was cycled through on January 4 and the other two were completed on January 15.

7.2.1.2 Idle Test Scheduling

Service was performed on failed idle test cars starting December 22 and was completed December 24 with the exception of one car that required additional work (January 6) and five cars that were identified as needing major engine work. These cars were deferred until all major engine work requirements were identified in the Key Mode and the Diagnostic tests. Based on an evaluation of economic, technical, and statistical considerations, four of the five vehicles requiring major work were omitted, and final 7-mode tests were completed January 18. The vehicle chosen for major repair was completed January 20.

Table 7-4. Schedule for Initial Testing

Test Code	Test Regime	Test Vehicles Per Day	Scheduled Test Dates
A	Certificate of Compliance Test	15	11/30, 12/3
B	Idle test	15	12/1, 12/4
C	Key Mode test	10	12/2, 12/7, 12/8
D	Diagnostic emission test	10	12/9, 12/10, 12/11

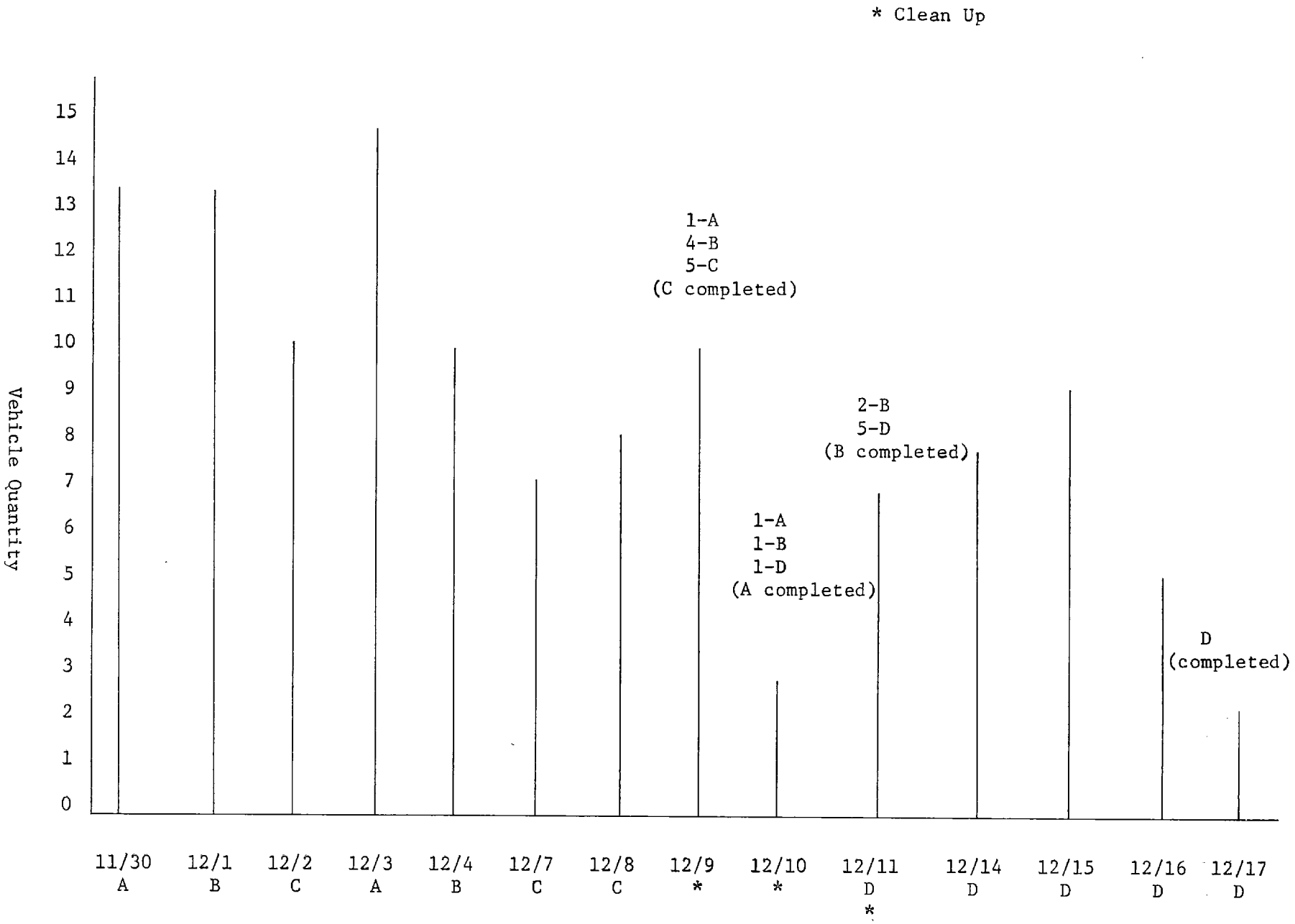

Figure 7-1. Test Status for Initial Testing

7.2.1.3 Key Mode Test Scheduling

Key Mode service commenced at the rate of five cars per day on January 4. Two cars required additional service on January 8 and three cars were deferred for major engine work. The two vehicles not chosen for major engine work and the one that did receive a valve job were given final 7-mode tests by January 15. One car was not available for retest until January 20, due to owner's vacation.

7.2.1.4 Diagnostic Test Scheduling

Diagnosis of cars failing the diagnostic emission test began January 7. Five cars per day were scheduled but it quickly became apparent that diagnosis time was greater than anticipated. Vehicle retests after key mode servicing and clean-up from other tests also caused delays. In addition, two different crews were utilized in the learning phase with both experiencing learning curve problems. Figure 7-2 is a plot of elapsed time for diagnosis versus tested vehicle. Figure 7-3 shows diagnostic time as a function of chronological date. Diagnostic service and retest was completed on January 20. Emphasis has been placed on the importance of diagnosis completion time in the main test program.

7.2.2 Vehicle Dispatching

The vehicles used for the learning phase were chosen from vehicles volunteered by Northrop employees. This eliminated the need for picking up and delivering cars at the participant's residence or place of business, as will be required during the main testing phase. A general description of the vehicle dispatching procedures and controls follow.

A set of three computer tab cards is generated for each test vehicle. Each card contains the vehicle number, description, and test to be performed. Card No. 1 also contains the name, address, and telephone number of the participant. Card No. 2, the test card, is color coded as to test type.

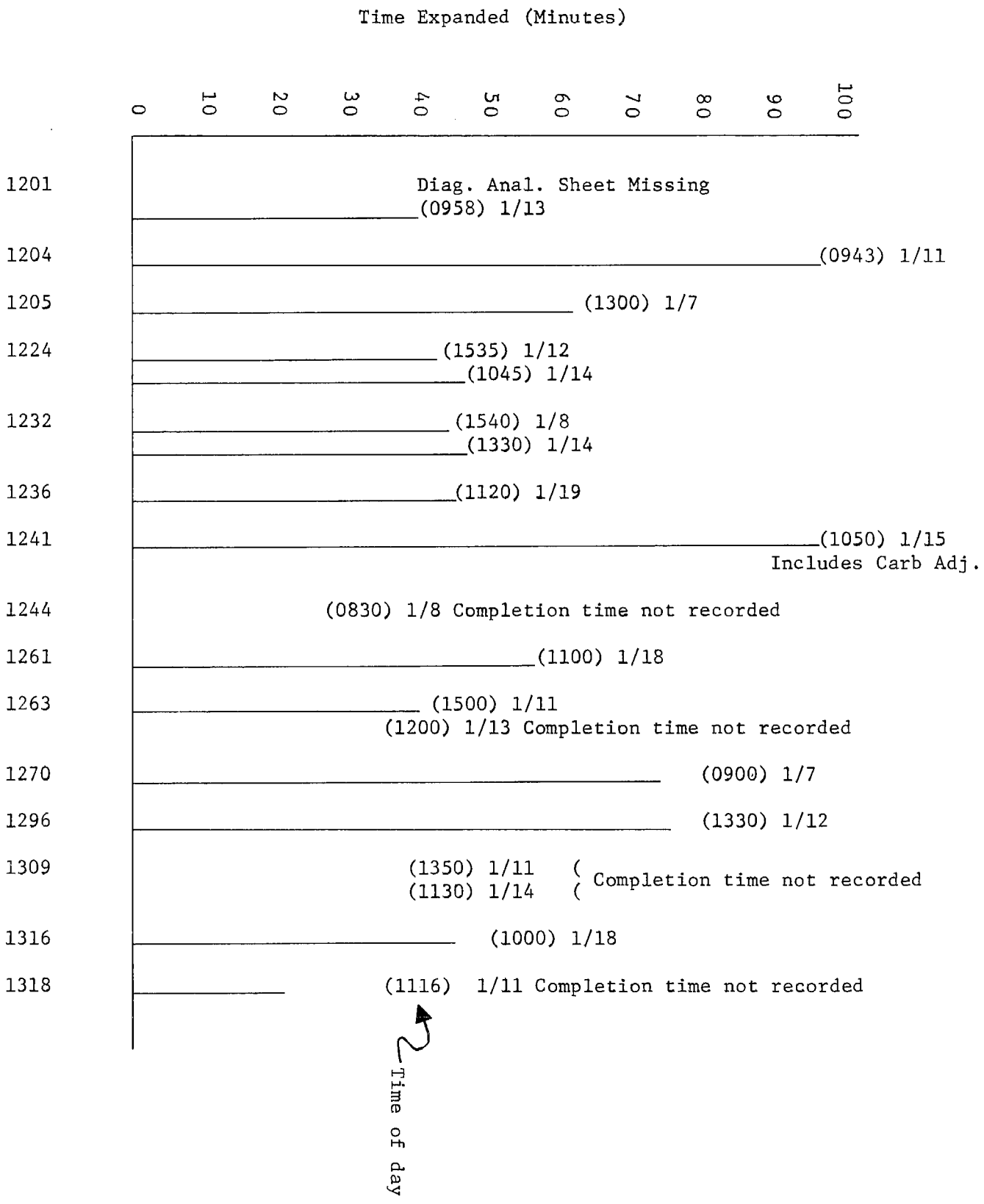

Figure 7-2. Diagnostic Time by Car Number

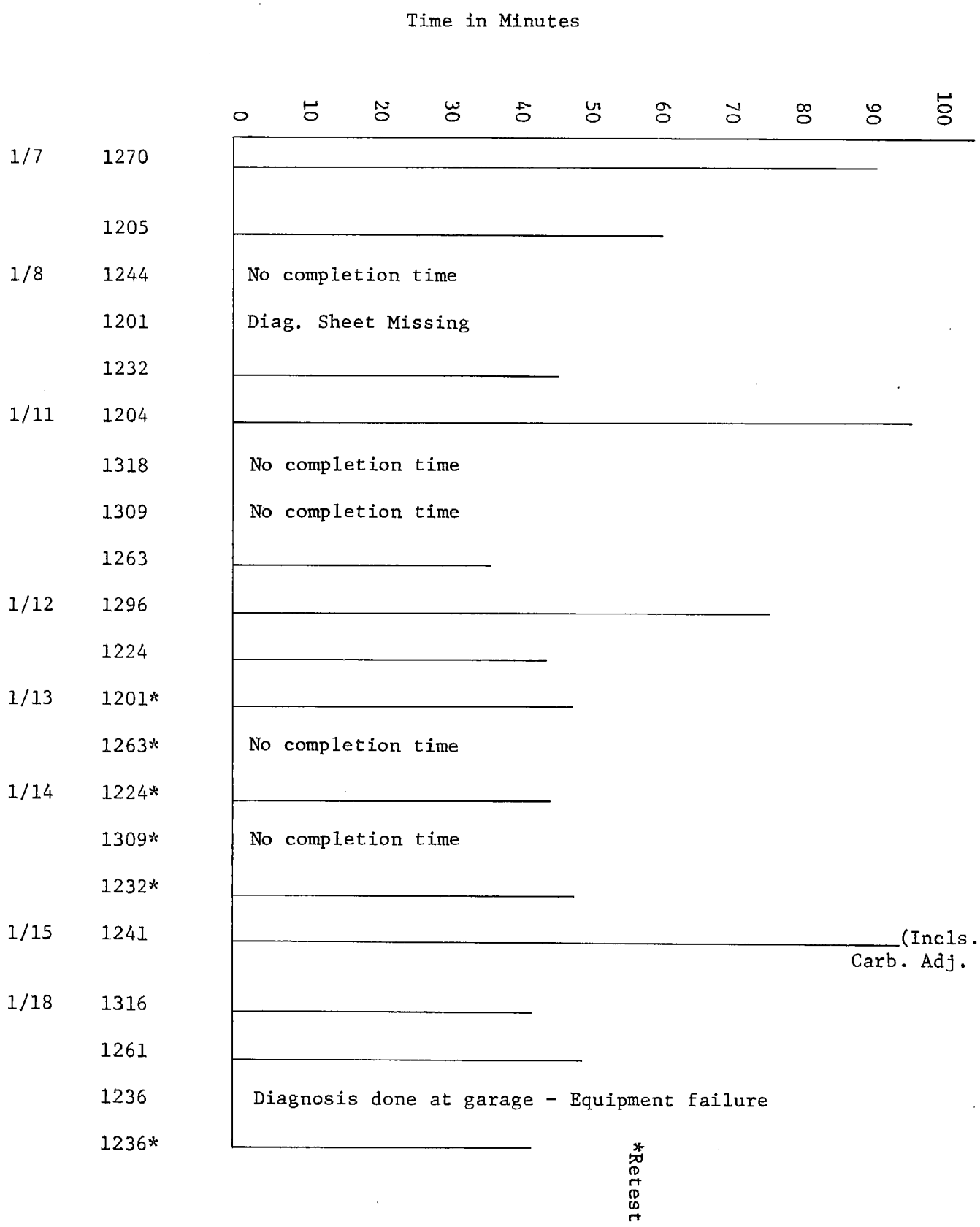

Figure 7-3. Diagnostic Time - Order of Performance

On the scheduled date, those cards corresponding to vehicles affected are placed in the time card racks located in the test area. This is accomplished after the vehicle availability has been confirmed with the owner. Vehicles arriving at the test facility are parked in numbered stalls and keys are placed on correspondingly numbered hooks in the Test Control office. Card No. 1 is placed in the vehicle and remains there until the vehicle is ready for return to the participant. Cards No. 2 and No. 3 are subsequently placed in the "On Hand" rack. Test personnel retrieve cards from this rack. When a test vehicle requires maintenance servicing, test personnel place cards No. 2 and No. 3 in the "Service Required" rack. The driver retracts cards No. 2 and No. 3 from the "Service Required" rack and places card No. 2 in the corresponding "Out for Service" rack. The designated service center will have been entered by the Test Control office on the reverse side of tab card No. 3. The vehicle is then delivered to the maintenance facility.

On notification of service completion, the Test Control office dispatches the driver to retrieve the serviced vehicle. The tab card No. 2 is retracted from the "Out of Service" rack, stamped "RETEST", and placed in the "Retest" rack along with the No. 3 card. The service center repair invoice is placed in file folder for that car. Upon satisfactory completion of retesting, test personnel place tab cards No. 2 and No. 3 in the "Return to Participant Pending" rack. The Test Control office notifies the participant that his car is ready for pick-up.

In the main testing program, vehicle dispatching will be slightly different. When pick-up at a participant's residence (or place of business) is required, the driver will be dispatched with a loan car and the three tab cards. At the participant's residence, the signed Northrop Vehicle Loan Agreement and a loan car receipt (signature on the reverse side of card No. 1) are obtained. The loan agreement will have been mailed to the participant in advance of the pick-up date, to allow sufficient time for perusal and comprehension. The vehicle will then be delivered to Northrop for testing.

Upon completion of testing, the vehicle and driver will be dispatched to the participant's residence after verifying that the participant will be available to receive the car. Following verification that the vehicle has been returned in satisfactory physical condition, the participant signifies receipt on the contract agreement. The loan car is returned to the test area, and all three tab cards are placed in the "Return to Participant - Completed" rack.

In those cases where the participant delivers his vehicle to Northrop, the Test Control office will have provided the Security Guard office with the names of the participants. The guard will direct the participant to the Test Control office where the necessary signatures on the tab card for the loan car and the loan agreement are obtained. Upon completion of the test and maintenance activities, the Test Control office will make the necessary arrangements to return the participant's vehicle and accept the loan car. The transfer of vehicles will be consummated along with the affixing of the required signatures as discussed previously.

7.2.3 Data Management

All original data for each car is stored in file folders identified by car number. This original data consists of the participant acceptance information, the loan agreement computer tab cards for vehicle routing, the baseline 7-mode computer printout; the emission test results for tests B, C, and D; Idle test adjustment measurements, Key Mode report cards, and Diagnostic analysis sheets; original repair invoices; retest printouts; and the final 7-mode printout.

Data is extracted from the baseline 7-mode test, the emission test results, any retest results, and the final 7-mode test, and transferred to computer coding forms to be keypunched for inclusion in the study's data base. Likewise, data from the repair invoices is extracted and broken down into labor actions, labor costs, parts replaced, and parts cost. This data is also coded in a form ready for keypunching. The coding format was chosen so that manual tabulation could easily be performed during the learning phase where there are fewer entries. This also allows for a check of keypunch accuracy.

The data base created during the learning phase will be available for inclusion into, or to contrast with, the main study's data base. Statistical analysis will be performed on the data base separately and in combination. The statistical analysis computer package will not be available until after the learning phase has been completed. Manual analysis of the learning phase results are presented in paragraph 7.5.

7.3 TEST REGIME EMISSION LIMITS ESTABLISHMENT

It was necessary to establish limits designed to fail 50 percent of the cars tested. Guidelines are provided in the request for proposal for the Idle test. Clayton Manufacturing Company provided guidelines in the establishment of Key Mode test limits. These guidelines were weighed against actual measured values for the 120 learning phase test cars.

7.3.1 Certificate of Compliance Limits

All cars in the Certificate of Compliance test regime will be sent out for service, therefore, no pass/fail limits are necessary.

7.3.2 Idle Test Limits

The test limits shown in Table 7-5 were used initially. These limits failed 21 of the 30 cars tested in at least one of the two failure modes, HC and CO. NO_x was measured at 2500 rpm but was not used as a failure mode.

To determine which 15 of the 30 cars were to be sent for service, all cars that failed both HC and CO were sent out and then those highest valued single failures were chosen. Seven exhaust emission controlled cars and eight uncontrolled cars were selected for service. Table 7-6 shows the cars identified for service and the modes failed. Table 7-7 shows the ranked order of measured values for HC, CO, and NO_x. The cars chosen for service will affect the values identified by the asterisk (*). Lines of demarcation indicate the median value for each category. Note that some asterisked cars are within the acceptable limits. This is due to their exceeding the limits in another category.

Table 7-5. Idle Test Failure Limits

Category	HC (ppm)	CO (%)	NO_x (ppm)
Controlled Cars	250	4.0	-
Uncontrolled Cars	700	5.0	-

Table 7-6. Idle Test Vehicles for Service

Note: (X) = Failure Mode

Category	HC (ppm)	CO (%)	NO_x (ppm)
Controlled Cars:			
1212	(X) 9999+	(X) 10.96	149
1225	(X) 580	2.11	671
1228	(X) 268	(X) 4.84	197
1238	(X) 294	3.91	553
1272	(X) 521	(X) 5.39	573
1275	(X) 437	(X) 9.63	434
1315	(X) 307	(X) 6.16	711
Uncontrolled Cars:			
1209	(X) 9999+	(X) 10.96	160
1229	(X) 800	(X) 7.33	957
1230	(X) 1155	(X) 10.24	808
1260	(X) 1213	(X) 5.53	558
1273	504	(X) 8.95	493
1281	(X) 772	(X) 5.24	761
1297	(X) 831	(X) 9.93	490
1314	(X) 853	(X) 9.09	581

7.3.3 Key Mode Test Limits

The results of Clayton Manufacturing Company's New Jersey tests were used as a guideline in initially determining which cars would be sent out for service. These failure limits are shown in Table 7-8. It was estimated that these limits would fail about 50 percent of the cars tested. The limits, in fact, caused failures in at least one mode for 20 of the 30 cars tested. Sixteen of these 20 failures were on uncontrolled cars and four were controlled cars. Six controlled cars and nine uncontrolled cars were selected for service based on greatest number of failure modes. It was determined later that one of the initial groups of controlled cars,

Table 7-7. Ranked Order of Idle Test Results

Note: * = Affected by Services

HC		CO		NO_x @2500 RPM	
Controlled	Uncontrolled	Controlled	Uncontrolled	Controlled	Uncontrolled
* 9999+	* 9999+	* 10.96	* 10.96	1229	2212
* 580	* 1213	* 9.63	* 10.24	934	* 957
* 521	* 1155	* 6.16	* 9.93	846	900
* 437	* 853	* 5.39	* 9.09	822	* 808
360	* 831	* 4.84	* 8.95	* 711	* 761
* 307	* 800	4.59	8.41	* 671	* 581
* 294	* 772	* 3.91	* 7.33	* 573	* 558
* 268	534	3.45	6.80	* 553	532
215	* 504	3.25	6.36	* 434	516
182	503	2.68	5.97	321	506
177	461	* 2.11	* 5.53	231	* 493
156	401	1.48	* 5.24	* 197	* 490
125	387	1.33	4.20	164	399
81	343	0.11	4.08	* 149	295
	311		3.44		253
	194		0.07		* 160

Table 7-8. Key Mode Test Failure Limits

Category	Idle	Low Cruise	High Cruise
Controlled:			
HC, ppm	290 - 350	240 - 300	220 - 300
CO, %	3.0 - 4.0	2.5	2.0 - 2.5
Uncontrolled:			
HC, ppm	700 - 800	450 - 550	450 - 550
CO, %	5.5 - 7.0	3.5	3.0 - 3.5

a 1966 Chevrolet, was, in fact, uncontrolled causing an imbalance in the controlled/uncontrolled car ratio. Two of the controlled cars had to be failed arbitrarily to obtain a total of six, since only four controlled cars failed the limits of Table 7-8. Table 7-9 lists the cars sent for service and the modes in which they failed. Table 7-10 is the ranked order of measured Key Mode values.

7.3.4 Diagnostic Test Limits

The diagnostic test limits were initially chosen by observing the ranked emission test results in search of clear break points in the data. An initial iteration through the initial test results gave seven controlled cars and 14 uncontrolled cars with failures in one or more modes. All seven controlled cars were sent for service. All uncontrolled cars with multiple failures were sent for service. This provided seven of eight cars needed to provide a 50 percent failure rate. The eighth car, number 1270, was chosen because it had the worst idle HC for all cars in this test. Based on this approach, the initial limits for the diagnostic test are shown in Table 7-11.

The cars and their failure modes are given in Table 7-12 and the ranked order of diagnostic emission test results is given in Table 7-13.

One of the uncontrolled cars, number 1249, selected for service, could not be made available for servicing so car number 1236, with one of the worst idle CO measurements was substituted.

Table 7-9. Key Mode Test Vehicles for Service

Note: (X) = Failure Mode

Category	Idle		Low Cruise		High Cruise	
Controlled Cars:	HC, ppm	CO, %	HC, ppm	CO, %	HC, ppm	CO, %
1214	(X) 292	(X) 6.10	171	0.50	201	2.47
1235	(X)1549	0.98	(X)746	1.41	(X)228	1.27
1256	(X) 537	(X) 4.42	33	0.92	30	0.98
1276 (Arbitrary)	137	(X) 2.53	130	1.09	92	0.88
1283	251	(X) 5.22	183	0.11	125	0.12
1312 (Arbitrary)	83	(X) 2.63	87	1.48	86	1.21
Uncontrolled Cars:						
1234	(X) 829	4.52	288	(X)3.52	153	2.22
1239	344	(X) 7.27	295	(X)7.79	140	0.97
1242	(X)1339	4.58	(X)561	(X)9.72	378	(X)6.13
1257	(X) 793	(X)10.95	442	(X)4.49	290	2.23
1268	275	4.83	273	2.69	278	(X)4.31
1279	353	(X) 6.48	381	(X)4.56	293	(X)3.39
1288	(X) 862	(X) 6.25	236	(X)6.18	229	(X)7.10
1294	(X)9999+	(X)10.97	191	1.63	92	0.26
1305	(X)1334	(X)10.94	(X)683	(X)7.46	425	(X)4.04

Table 7-10. Ranked Order of Key Mode Test Results

Note: * = Affected by Service

Idle				Lo Cruise				Hi Cruise			
HC		CO		HC		CO		HC		CO	
Cont	Uncont	Cont	Uncont	Cont	Uncont	Cont	Uncont	Cont	Uncont	Cont	Uncont
*1549	*9999+	*6.10	*10.97	*746	*683	*1.48	*9.72	*228	*425	*2.47	*7.10
* 537	*1339	*5.22	10.97	*183	*561	*1.41	*7.79	*201	*378	*1.27	*6.13
* 292	*1334	*4.42	*10.95	181	*442	*1.09	*7.46	129	296	*1.21	*4.31
* 251	1270	*2.63	*10.94	177	411	0.95	*6.18	*125	*293	*0.98	*4.04
197	1024	2.55	9.72	*171	410	*0.92	*4.56	116	*290	*0.88	*3.39
177	1009	*2.53	9.57	163	406	0.63	*4.49	115	286	0.72	3.30
177	963	2.42	8.73	138	*381	*0.50	3.80	113	*278	0.56	*2.23
* 138	* 862	2.16	8.50	*130	334	0.22	*3.52	109	273	0.52	*2.22
129	* 829	1.59	8.16	113	330	0.18	3.22	* 92	*229	*0.12	1.69
108	* 793	1.29	* 7.27	100	*295	*0.11	3.20	92	218	0.11	1.51
* 83	689	1.14	6.75	* 87	*288	0.10	2.98	* 86	206	0.09	1.50
56	668	*0.98	* 6.48	* 33	284	0.09	2.79	* 30	177	0.08	1.17
	634		* 6.25		*273		*2.69		165		1.04
	398		* 4.83		243		2.21		*153		*0.97
	357		* 4.58		*236		1.82		*140		0.53
	* 353		* 4.52		*191		*1.63		117		0.30
	* 344		4.30		191		1.05		* 92		*0.26
	* 275		2.26		162		0.92		92		0.21

Table 7-11. Diagnostic Test Failure Limits

	Idle	60 mph/loaded	50 mph/8hp	Decel.
Controlled				
HC, ppm	300	250	250	2000
CO, %	4.0	5.5	2.5	-
Uncontrolled				
HC, ppm	700	400	550	9000
CO, %	7.0	5.5	3.5	-

7.4 VEHICLE POST-MAINTENANCE TEST RESULTS

7.4.1 Certificate of Compliance

Twenty-seven test vehicles were delivered to various inspection stations for certificate of compliance inspection and system certification. The receiving station was instructed to perform system inspection and certification in accordance with current California Highway Patrol Handbook for Installation and Inspection Stations. Twelve controlled vehicles with factory installed exhaust emission control and crankcase ventilation systems were selected. Eighteen uncontrolled vehicles with unknown types of positive crankcase ventilation (PCV) systems were also selected. However, three of the uncontrolled vehicles were found not to have a PCV system installed. It was decided with concurrence of the ARB that these vehicles would not have a device installed and therefore were excluded from the test group.

All vehicles selected for certificate of compliance evaluation were tested with seven-mode hot cycles to establish baseline emission values prior to certificate of compliance inspections and retested after inspection completion to evaluate any change in emissions. The average pre-test and post-test vehicle baseline values for controlled vehicles are given in Tables 7-14 and 7-15. The values for uncontrolled vehicles are listed in Tables 7-16 and 7-17. Table 7-18 shows the average pre-test and post-test emission levels of each set of vehicles and all vehicles combined.

Table 7-12. Diagnostic Test Vehicles Chosen for Service

Note: CO = Failure Modes

	Idle		60 mph/loaded		50 mph/8 hp			Decel.
Controlled	HC, ppm	CO, %	HC, ppm	CO, %	HC, ppm	CO, %	NO_x, ppm	HC, ppm
1204	128	0.80	142	3.13	170	(X)3.09	1342	183
1205	284	(X) 5.64	223	4.80	176	1.41	2405	514
1232	222	3.29	126	2.92	(X)273	0.59	1629	1122
1241	156	2.02	156	2.19	140	0.54	1736	(X)5771
1244	(X) 378	(X) 5.44	191	2.98	(X)393	0.29	3060	1559
1261	(X) 395	(X) 8.46	196	5.17	167	1.32	2540	(X)9999+
1296	(X) 382	3.89	(X) 275	(X)6.31	175	1.21	1709	557
Uncontrolled								
1201	(X) 990	(X)10.21	310	5.30	(X)795	1.28	2856	2974
1224	403	3.37	(X)5801	(X)6.63	(X)624	(X)8.71	561	(X)9999+
1236	410	(X) 8.47	212	0.76	278	2.77	2061	8109
1263	409	5.01	376	(X)9.55	380	(X)5.51	261	8194
1270	(X)2474	1.93	325	1.51	393	1.63	1161	3321
1309	(X)2107	0.13	(X) 487	2.12	396	2.32	1952	1189
1316	638	(X)10.58	164	4.05	184	0.72	3642	(X)9999+
1318	(X) 731	6.01	362	4.88	(X)580	(X)6.61	587	6821

Table 7-13. Ranked Order of Diagnostic Emission Measurements

Note: * = Measurements Affected by Service

Idle		60 mph/loaded		50 mph/8 hp			Deeel.
HC	CO	HC	CO	HC	CO	NO_x	HC
Controlled							
* 395	* 8.46	* 275	*6.31	*393	*3.09	3931	*9999+
* 382	* 5.64	* 223	5.64	*273	*1.41	*3060	*5771
* 378	* 5.44	207	5.62	214	*1.32	2908	1804
* 284	* 3.89	* 196	*5.17	*176	*1.21	2575	*1559
* 222	* 3.29	* 191	*4.80	*175	1.14	*2540	1300
176	2.66	183	4.02	170	0.93	*2405	*1122
171	2.66	* 156	3.31	*167	*0.59	2150	952
161	* 2.02	* 142	*3.13	*140	*0.54	2105	822
* 156	1.87	137	*2.98	140	0.30	*1736	629
147	1.75	* 126	2.98	101	*0.29	*1709	589
* 128	1.60	108	*2.92	92	0.24	*1629	* 557
121	1.26	93	2.52	57	0.17	*1342	* 514
95	* 0.80	87	*2.19	39	0.16	577	488
70	0.43	44	2.10	31	0.09	498	* 183
Uncontrolled							
*2474	*10.58	*5801	*9.55	*795	*8.71	*3642	*9999+
*2107	10.34	690	6.97	*624	*6.61	3484	*9999+
1535	*10.21	* 487	*6.63	*580	*5.51	*2856	9999+
* 990	* 8.47	* 376	*5.30	449	4.30	2512	9999+
* 731	7.53	* 362	5.19	447	4.09	2352	9114
* 635	6.75	355	4.91	*396	3.24	*2061	8621
598	* 6.01	* 325	*4.88	*393	3.18	*1952	8501
542	6.01	* 310	4.43	*380	3.04	1569	*8194
538	5.31	291	*4.05	338	*2.77	1496	*8109
444	5.16	255	4.01	332	*2.32	1456	*6821
* 410	* 5.01	249	3.22	*278	*1.63	*1161	*3321
* 409	3.51	* 212	*2.12	263	1.32	1016	3120
409	* 3.37	192	2.05	257	*1.28	774	*2974
* 403	* 1.93	* 164	1.93	257	*0.72	* 587	1456
396	1.75	162	*1.51	221	0.46	* 561	*1189
395	* 0.13	119	*0.76	*184	*0.43	* 261	710

Table 7-14. Controlled Vehicles Emissions in Concentrations (NO_x Uncorrected)

Test Vehicle				Pre-Test Vehicle Baseline			Post-Test Vehicle Baseline		
No.	Yr.	Make	Mileage	HC	CO	NO_x	HC	CO	NO_x
1211	59	Olds	35,092	214	1.10	1,606	187	0.56	1,710
1215	66	VW	37,244	1,290	6.26	680	776	4.64	690
1221	69	DATS	19,749	247	0.97	2,805	201	0.50	2,853
1233	67	PONT	60,147	212	1.20	1,627	178	1.26	1,312
1243	68	PLY	40,577	232	0.73	2,785	102	0.30	2,320
1246	68	MERC	28,333	678	1.81	1,602	451	0.84	1,346
1264	68	CHEV	32,987	443	2.18	1,936	489	1.99	2,046
1269	66	PONT	91,255	256	2.46	1,163	254	2.34	1,133
1287	70	BUIC	13,281	166	1.21	1,475	182	1.54	1,499
1299	70	FORD	2,473	208	2.19	1,277	173	0.48	1,290
1308	67	CAD	40,478	279	3.45	993	286	3.89	812
1313	69	PONT	25,626	355	3.32	1,650	390	2.86	2,285
1317	70	VW	16,432	130	0.47	1,767	124	0.78	1,895
Emission Averages				285	1.75	1,724	256	1.53	1,708

Table 7-15. Controlled Vehicles Emissions in Grams per Mile

Test Vehicle				Pre-Test Vehicle Baseline			Post-Test Vehicle Baseline		
No.	Yr.	Make	Mileage	HC	CO	NO_x	HC	CO	NO_x
1211	69	OLDS	35,092	2.91	28.13	6.48	2.55	14.32	6.44
1215	66	VW	37,244	14.74	134.30	2.26	5.00	56.22	1.23
1221	69	DATS	19,749	1.96	14.43	6.34	1.59	7.44	6.31
1233	67	PONT	60,147	3.04	32.40	6.64	2.56	34.01	5.52
1243	68	PLY	40,577	2.68	15.86	9.54	1.87	6.51	8.01
1246	68	MERC	28,333	7.84	39.33	5.43	5.22	17.82	4.38
1264	68	CHEV	32,987	6.03	55.75	7.55	6.66	50.89	7.48
1269	66	PONT	91,255	3,68	66.43	4.77	3.65	63.18	4.72
1287	70	BUIC	13,281	2.10	28.82	5.38	2.30	36.68	5.48
1299	70	FORD	2,473	2.83	56.02	4.99	2.35	37.85	4.95
1308	67	CAD	40,478	4.01	93.15	4.24	4.11	105.04	3.47
1313	69	PONT	25,626	4.50	79.89	5.87	4.94	68.12	8.19
1317	70	VW	16,432	1.03	7.00	4.01	1.09	12.91	4.61
Emission Averages				3.55	43.09	5.93	3.25	37.84	5.79

Table 7-16. Uncontrolled Vehicle Emissions in Concentrations (NO_x Uncorrected)

Test Vehicle				Pre-Test Vehicle Baseline			Post-Test Vehicle Baseline		
No.	Yr.	Make	Mileage	HC	CO	NO_x	HC	CO	NO_x
1206	63	PONT	20,159	710	2.98	1,626	505	2.78	1,152
1226	62	DODGE	72,340	302	2.88	1,525	340	3.56	1,356
1245	64	OLDS	20,550	512	3.16	1,587	625	3.52	1,147
1248	60	BUICK	87,132	388	2.02	1,041	*	*	*
1253	63	CHEV	58,622	1,006	8.25	1,162	754	3.17	912
1265	65	CHEV	53,245	481	1.94	1,216	485	2.14	1,030
1274	65	CHEV	59,613	529	2.62	2,049	568	3.01	1,770
1293	60	FORD	103,391	658	1.13	1,499	354	0.79	1,643
1301	65	DODGE	50,244	505	3.00	1,422	302	2.36	1,321
1203	65	PONT	50,023	326	2.01	1,526	313	1.46	1,624
1302	63	CHRY	71,209	375	2.99	1,012	388	3.34	1,068
1304	64	FORD	57,537	552	3.15	1,887	469	2.28	1,896
1310	64	FORD	90.035	475	2.20	1,764	380	2.51	1,387
1319	60	VW	44,489	1,110	5.00	786	*	*	*
1240	58	PLY	81,133	465	1.87	2,973	341	1.31	3,335
1298	56	FORD	100,840	449	1.56	2,581	*	*	*
Average Uncontrolled				581	2.66	1,610	481	2.59	1,485

Table 7-17. Uncontrolled Vehicle Emission in Grams per Mile

Test Vehicle				Pre-Test Vehicle Baseline			Post-Test Vehicle Baseline		
No.	Yr.	Make	Mileage	HC	CO	NO_x	HC	CO	NO_x
1206	63	PONT	20,159	10.21	80.46	6.88	7.26	75.06	4.88
1226	62	DODGE	72,340	3.10	55.60	4.38	3.49	68.74	4.16
1245	64	OLDS	20,550	6.62	68.67	5.16	7.23	76.49	3.72
1248	60	BUICK	87,132	5.58	54.54	4.20	*	*	*
1253	63	CHEV	58,622	10.35	62.76	3.30	7.54	61.20	2.75
1265	65	CHEV	53,245	5.56	42.16	4.18	5.61	46.50	3.51
1274	65	CHEV	59,613	6.71	62.40	7.49	7.20	71.70	6.32
1277	61	CHEV	63,402	7.75	28.11	7.41	8.15	43.83	6.90
1293	60	FORD	103,391	8.96	28.90	5.97	4.82	20.20	6.14
1301	65	DODGE	50,244	5.84	65.20	4.89	3.50	51.28	4.46
1203	65	PONT	50,823	4.44	51.47	5.88	4.26	37.34	6.26
1302	63	CHEV	71.209	5.10	76.47	3.95	5.21	85.43	4.10
1304	64	FORD	57,537	7.93	85.05	8.07	6.74	77.76	7.74
1310	64	FORD	90,035	6.47	56.27	7.13	5.17	65.74	5.57

Table 7-17. Uncontrolled Vehicle Emission in Grams per Mile (Continued)

Test Vehicle				Pre-Test Vehicle Baseline			Post-Test Vehicle Baseline		
No.	Yr.	Make	Mileage	HC	CO	NO_x	HC	CO	NO_x
1319	60	VW	44,489	7.16	60.59	1.41	*	*	*
1240	58	PLY	81,133	5.89	44.54	11.62	4.32	31.20	11.77
1298	56	FORD	100,840	5.19	33.90	8.58	*	*	*
Average Emissions				7.09	60.41	5.51	5.69	57.89	5.29

*Vehicles without FCV Systems

Table 7-18. Uncontrolled/Controlled Vehicle Emission Averages

	Pre-Test			Post-Test		
Averages in Concentrations	HC	CO	NO_x	HC	CO	NO_x
Controlled	285	1.75	1,724	256	1.53	1,708
Uncontrolled	581	2.66	1,610	481	2.59	1,485
Average	463	2.30	1,656	391	2.16	1,574
Averages in Grams Per Mile	HC	CO	NO_x	HC	CO	NO_x
Controlled	3.55	43.09	5.93	3.25	37.84	5.79
Uncontrolled	7.09	60.41	5.51	5.69	57.89	5.29
Average	5.67	53.48	5.68	4.71	49.87	5.49

Ave Veh Weight
3700 lb
3800

CO
HC

Emission changes, service costs, and repair actions are described in Tables 7-19 and 7-20. Test effectiveness as listed in the net change (increase or decrease) in each emission value for each vehicle including group averages. Emission increases are noted in parenthesis. Individual service costs and averages are listed for controlled, uncontrolled, and all vehicles combined. Repair actions are coded with a code description appearing in Table 7-21. Tables 7-22 and 7-23 identify emission changes versus costs and average reduction versus costs.

Table 7-19. Controlled Vehicles Emission Reduction and Repairs

TV No.	Reductions in Concentrations HC	CO	NO_x	Repair Action	Service Costs
1211	27	.54	(104)	1, 3	7.50
1215	514	1.62	(10)	1, 2, 3, 4, 5	12.61
1221	46	.47	(48)	1, 3	6.00
1223	34	(.06)	315	1	12.60
1243	70	.43	465	1, 2, 3, 4	10.55
1246	263	.99	256	1, 2, 3, 4	6.80
1264	(46)	.19	(110)	1	6.85
1269	2	.12	30	1	12.60
1287	(16)	(.33)	(24)	1, 9	12.45
1299	35	.71	(13)	1, 2, 3, 6	5.70
1303	(7)	(.44)	181	1	8.10
1313	(35)	.46	(635)	1	5.00
1317		(.31)	(128)	1	4.50
Avg.	29	.22	16		8.22

( ) = Value Increase

Table 7-20. Uncontrolled Vehicles Emission Reduction and Repairs

NO.	HC	CO	NO_X	Repair Action	Service Costs
1206	205	.20	474	1	3.10
1226	(38)	(.68)		1	3.10
1245	(53)	(.36)	440	7(A)	12.38
1248	*	*	*	*	*
1253	272	.08	250	7(A)	9.99
1265	(4)	(.20)	186	7(A)	5.00
1274	(31)	(.34)	279	1	3.00
1277	(32)	(.66)	129	7(A)	2.50
1293	304	.34	(144)	7(A)	3.69
1301	203	.64	101	7(A)	5.65
1203	13	.55	(98)	7(A)	9.99
1302	(8)	(.35)	(56)	7(A)	10.95
1304	83	.87	(9)	1	3.00
1310	95	.36	377	1	2.00
1319	*	*	*		*
1240	124	.56	(362)	1	3.10
1298	*	*	*	*	*
Avg.	80	0.01	123		6.02
Average Emission Change - All Vehicles				( ) Value Increase	
	68	.13	76		7.06

Table 7-21. Repair Action Code

Code No.	Repair/Adjustment Action
1	Inspect/Test and Certify Compliance
2	Adjust Engine RPM
3	Adjust Idle Mixture
4	Adjust Ignition Timing/Dwell
5	Repair Ignition System/Replace Components
6	Repair/Replace Carburetor
7	Emission Control System Repair/Replace
(A)	PCV - Crankcase Ventilation
(B)	Exhaust Control
8	Heat Riser Repair
9	Air Cleaner Replacement

Table 7-22. Emission Changes Versus Costs

Concentrations

No.	Test Vehicles	Pre-Test Vehicle Baseline			Post-Test Vehicle Baseline			Cost
		HC	CO	NO_x	HC	CO	NO_x	
12	Controlled	285	1.75	1724	256	1.53	1708	$8.22
15	Uncontrolled	581	2.66	1610	481	2.59	1485	$6.02
27	All Vehicles	449	2.26	1660	381	2.12	1584	$7.06
				Grams per Mile				
12	Controlled	3.55	43.09	5.93	3.25	37.84	5.79	$8.22
15	Uncontrolled	7.09	60.41	5.51	5.69	57.89	5.29	$6.02
27	All Vehicles	5.51	52.71	5.70	4.61	48.97	5.51	$7.06

Table 7-23. Average Reductions/Increase

Concentrations

No.	Test Vehicles	HC	CO	NO_x	Service Costs
12	Controlled	29	.22	16	$8.22
15	Uncontrolled	100	.07	125	$6.02
27	All Vehicles	68	.13	76	$7.06
		Grams per Mile			
12	Controlled	.30	5.25	.19	$8.22
15	Uncontrolled	1.40	2.52	.22	$6.02
27	All Vehicles	.91	3.73	.20	$7.06

Certificate of Compliance

7.4.1.1 Analysis of Controlled Vehicles Test Results

Controlled vehicles emissions were reduced by 29 PPM HC 0.22 CO and 16 PPM NO_x at an average inspection/service cost of $8.22. Analysis of emission changes as related to inspection/service actions performed at the selected garages shows that six vehicles received no adjustments as a result of the inspection. Three vehicles apparently had idle mixture adjustment; three had idle mixture, timing and RPM adjustments; one vehicle had distributor points and vacuum advance units replaced; and another had the air cleaner replaced.

The six vehicles which were inspected and received no adjustments shows a slight improvement in HC and CO with a larger increase in NO_x. The change in HC and CO were not appreciable, however, the NO_x increased for no apparent reason. Since the vehicles were not adjusted the data could not be included in drawing any effectiveness conclusions.

Emission Change - Controlled Vehicles

Inspection Only (Average) Six Vehicles

	HC	CO	NO_x
Increase	0	0	233 ppm
Decrease	7.6 ppm	0.14%	0

Three vehicles received idle mixture adjustments as a result of air-fuel ratio measurements during the inspection procedure. In all cases the adjustments resulted in a significant reduction in CO, a slight reduction in HC, and an increase in NO_x.

Emission Change - Controlled Vehicles

Idle Mixture Adjustment - Three Vehicles

	HC	CO	NO_x
Increase	0	0	0
Decrease	36 ppm	0.57%	55 ppm

Three vehicles received idle mixture, idle RPM and timing adjustments. Distributor breaker points were replaced and vacuum advance adjusted on one vehicle, a PCV valve replaced on another. Third vehicle had no parts replaced. The average reduction on each vehicle was significant including the NO_x reduction while the cost was minimal.

Emission Change - Controlled Vehicles

Idle Mixture, RPM and Timing Adjustment - Three Vehicles

	HC	CO	NO_x
Increase	0	0	0
Decrease	282 ppm	1.01%	237 ppm

7.4.1.2 Uncontrolled Vehicles Test Results

Average emission reduction for uncontrolled vehicles was 100 ppm HC, 0.13% CO, and 125 ppm NO_x. The average inspection/service cost was $6.02 per vehicle. Of the 14 uncontrolled vehicles, six were inspected and compliance certified without further maintenance. Eight vehicles received PCV maintenance. Five PCV valves were replaced, two were cleaned and a breather cap was replaced. The emission change data from vehicles either receiving no maintenance or service adjustments yet showing differences in pre- and post-emission levels could not be included in the analysis.

Emission Change - Uncontrolled Vehicles

Inspection Only - Six Vehicles

	HC	CO	NO_x
Increase			
Decrease	70 ppm	0.04%	155 ppm

Of the eight vehicles experiencing PCV system maintenance, three showed a marked improvement in emission, one a slight improvement, and four showed an increase in HC and CO with three of the four vehicles improving in NO_x.

Emission Change - Controlled Vehicles

PCV Maintenance

	HC	CO	NO_x
Average Increase (4 Vehicles)	24 ppm	0.39%	170 ppm (decrease)
Average Decrease (4 Vehicles)	198 ppm	0.40%	164
Composite Average (8 Vehicles)	87 ppm (decrease)	0	167 ppm (decrease)

7.4.1.3 Certificate of Compliance Test Regime Evaluation

Discounting the emission change from those controlled and uncontrolled vehicles which were not adjusted or repaired, the emission reduction of the 27 vehicles which received certificate of compliance inspections are shown below.

Emission Change - All Vehicles

	HC	CO	NO_x
Average Decrease	45 ppm	0.17%	81 ppm

at an average cost per vehicle of $7.06.

It is difficult to conclude from the weighted net change in emissions that there is a significant emission reduction in the test fleet, on an average. However, it should be noted that the average pre-test baseline emissions were relatively low, particularly in the uncontrolled group where the greatest decrease in hydrocarbons and nitrogen oxides were experienced. In all cases the exceptionally high emitters were identified and corrected with favorable results.

Inspection and service costs were nominal with a low of $2.00 to a high of $12.60 and in no reported cases were unnecessary repairs attempted. Although data from the Certificate of Compliance procedure is not conclusive at this early stage of the investigation, they appear to have several desirable advantages. These include (1) identification and repair of high emitters, (2) relatively low cost per vehicle, and (3) ease of implementation in a mandatory inspection center.

Improvement possibilities are in the area of documented procedures and inclusion of timing and mixture adjustment requirements for uncontrolled vehicles. Present procedures provide a general test, diagnostic, adjustment, and repair approach with reference to manufacturer's specifications for systems details. Inclusion of the detailed systems data in the inspection handbook could serve to provide improved training and understanding for the inspection mechanic. Inclusion of timing and mixture adjustment requirements for uncontrolled vehicles has significant possibilities of emission improvement particularly in the area of CO decreases.

7.4.2 Idle Mode Inspection Test

Thirty vehicles were selected for Idle Mode inspection testing, 15 post-1966 vehicles equipped with exhaust emission control systems and 15 pre-1966 vehicles. Each vehicle has been tested with seven-mode hot cycles to establish baseline emission values prior to testing by the Idle Mode procedures. Idle Mode test limits were established at levels sufficient to fail fifty percent of the controlled vehicles and fifty percent of the uncontrolled vehicles. Vehicles determined to have failed were delivered to selected repair stations for retesting, adjustment, and systems repair as determined by station maintenance personnel. When service operations were completed, the vehicle was returned to the test facility and retested using the Idle procedure.

Vehicles found not to meet established limits were recycled to the station for further maintenance as required. When the test vehicle was found to be in compliance, an additional seven-mode hot cycle test was performed to establish post-test baseline values for comparison with pre-test baseline to evaluate changes in emissions.

Table 7-24 lists the pre- and post-test baseline emission values of controlled and uncontrolled vehicles selected for service. Emission averages are shown for controlled, uncontrolled and all vehicles. Table 7-25 identifies the pre- and post-test values in grams per mile. Pre-test data of vehicles not selected for service is included in Table 7-26.

Table 7-24. Controlled/Uncontrolled Vehicles Exceeding Limits and Selected for Service-Emissions in Concentration

CONTROLLED									
Test Vehicle				Pre-Test Vehicle Baseline			Post-Test Vehicle Baseline		
No.	Yr.	Make	Mileage	HC	CO	NO_x	HC	CO	NO_x
*1212	67	VW	63,821	1,345	5.43	559	527	2.30	556
1225	68	OLDS	39,665	340	0.97	2,054	141	0.64	1,518
1228	69	PONT	24,265	433	5.98	802	291	2.01	1,693
1238	68	FORD	20,603	342	5.32	460	208	0.54	1,801
1272	67	CHEV	53,600	587	2.67	1,351	250	1.75	1,440
1275	69	CHEV	20,539	363	2.79	2,018	244	0.90	2,400
1315	66	FORD	62,111	348	1.91	2,565	283	0.50	2,514
Emission Average				402	3.27	1,541	236	1.05	1,894
UNCONTROLLED									
1209	63	VW	102,248	3,776	5.26	293	832	5.12	1,179
1229	65	PONT	40,737	667	3.15	2,121	527	6.45	447
1230	63	OLDS	77,448	655	5.99	644	430	2.60	1,493
1260	65	CHEV	56,532	641	5.24	621	449	4.00	694
1273	64	BUICK	73,840	364	3.28	957	276	1.51	1,730
1281	62	CHEV	51,150	782	3.28	1,596	692	3.23	991
1297	64	CHEV	77,567	782	3.46	1,424	511	1.98	1,190
1314	63	OLDS	172,898	673	5.29	562	539	1.59	1,461
Emission Average				1,076	4.49	975	531	3.20	1,082
Average All Serviced Vehicles				806	4.00	1,202	413	2.34	1,407

*Vehicle 1212 is an uncontrolled car. Averages were corrected to reflect this.

Table 7-25. Controlled/Uncontrolled Vehicles Exceeding Limits and Selected for Service (Grams Per Mile)

CONTROLLED									
Test Vehicle				Pre-Test Vehicle Baseline			Post-Test Vehicle Baseline		
No.	Yr.	Make	Mileage	HC	CO	NO_x	HC	CO	NO_x
*1212	67	VW	63,821	9.72	73.74	1.20	3.81	31.23	1.16
1225	68	OLDS	39,665	4.31	23.10	7.97	1.78	15.24	5.73
1228	69	PONT	24.265	5.89	152.96	3.25	3.96	51.41	6.61
1238	68	FORD	20,603	3.95	115.61	1.52	2.40	11.72	5.81
1272	67	CHEV	53.600	7.44	63.60	4.84	3.17	41.7	5.61
1275	69	CHEV	20.539	4.94	71.36	8.13	3.32	23.01	9.07
1315	66	FORD	62,111	4.74	48.85	9.42	3.85	12.78	9.59
Emission Average				5.21	79.25	5.86	3.08	19.73	7.08
UNCONTROLLED									
1209	63	VW	102,248	3.27	63.73	0.53	5.37	62.04	2.25
1229	65	PONT	40,737	7.72	68.45	7.31	6.10	140.17	1.43
1230	63	OLDS	77,448	8.92	153.22	2.46	5.85	66.50	5.59
1260	65	CHEV	56.532	8.13	124.82	2,28	5.69	95.29	2.46
1273	64	BUICK	73,840	3.98	65.85	3.06	3.19	32.81	5.64
1281	62	CHEV	51,150	10.65	83.90	6.05	9.42	82.62	4.53
1297	64	CHEV	77,567	8.04	66.81	4.22	5.25	38.22	3.44
1314	63	OLDS	112,898	9.16	135.32	2.26	7.34	40.66	6.04
Emission Average				7.73	92.87	3.26	5.78	65.51	3.61
Average All Vehicles				6.72	87.42	4.30	4.70	47.19	5.00

*Vehicle 1212 is an uncontrolled car. Averages were corrected to reflect this.

Table 7-26. Controlled/Uncontrolled Vehicles Not Exceeding Limits and Not Selected for Service

CONTROLLED									
Test Vehicle				Pre-Test Baseline Concentrations			Pre-Test Baseline Grams Per Mile		
No.	Yr.	Make	Mileage	HC	CO	NO_x	HC	CO	NO_x
1208	70	VW	08,199	151	0.32	2,351	1.74	6.95	7.81
1231	66	PLY	70,522	435	2.38	1,802	5.51	56.69	6.56
1247	69	CHRY	38,882	219	1.01	2,042	2.98	25.83	8.12
1286	68	BUICK	26.670	238	2.08	1,700	3.01	49.54	6.00
1311	70	FORD	02,230	107	0.61	1,181	1.23	13.25	4.08
1216	69	VW	19,622	154	0.62	2,482	1.47	11.73	7.79
1282	69	BUICK	08,885	117	0.71	2,110	1.59	18.15	7.82
Emission Average				203	1.10	1,953	2.50	26.02	6.88
UNCONTROLLED									
1237	62	COMET	47,747	304	0.71	2,312	3.12	13.70	6.90
1250	63	DART	59,406	717	2.94	1,817	8.30	63.89	6.12
1278	63	BUICK	79,001	415	2.48	1,459	4.80	53.89	4.89
1290	61	CHEV	07,763	388	2.87	962	5.28	73.41	3.74
1300	65	FORD	74,290	393	3.33	1,152	5.35	85.17	4.40
1306	64	FALCON	70,492	656	3.09	1,786	6.74	59.66	5.23
1320	63	FORD	81,562	611	2.77	1,721	7.75	65.98	6.11
1284	60	CHEV	67,036	396	1.97	1,513	5.02	46.92	5.57
Emission Average				482	2.52	1,590	5.80	57.82	5.37
Average All Vehicles				353	1.86	1,759	4.26	42.98	6.07

Idle mode inspection test results for all vehicles is identified in Table 7-27. Initial idle test results for vehicles not receiving service are listed in Table 7-27(A); Table 7-27(B) lists the initial test result, and the post-service test result for vehicles receiving service. Test values in parenthesis indicates emission values exceeding limits.

Test effectiveness/service costs and repair actions are included in Table 7-28. Test effectiveness as listed is the net change (increase or decrease) in each emission value for each vehicle including group averages. Emission increases are noted in parenthesis. Individual service costs and averages are listed for controlled, uncontrolled, and all vehicles combined. Repair actions are coded with a code description appearing in Table 7-29. Tables 7-30 and 7-31 identify emission changes versus service costs and average reductions versus costs.

7.4.2.1 Vehicle Analysis

Twelve vehicles selected for maintenance experienced Idle Mode emission level failures in both HC and CO values. Two vehicles failed in HC only and one vehicle in CO only.

Five of the vehicles failing both limits were improved through replacement of various ignition components and adjustments of idle speed, timing and idle mixture. One of the five, with valve failure, although significantly improved by adjustment and ignition system maintenance, was scheduled for major repair operations. Two of the five improved in all values as measured by seven-mode hot cycles post-service baseline testing, and two experienced a substantial increase in NO_x. However, the two vehicles increasing in NO_x had considerable decreases in CO values as a result of idle-mixture adjustments.

One of the five, No. 1281, was recycled to the garage for additional adjustments after initial maintenance. The vehicle, when retested by Idle Mode test procedures, still exceeded both HC and CO limit values; however, on the basis of improvements measured by seven-mode test it was decided to accept the vehicle. The vehicle scheduled for valve maintenance had emission changes from HC 910, CO 2.84 as measured after initial service to HC 527, CO 2.36, after repair.

Table 7-27. Idle Mode Inspection Test, Inspection Test/Post-Service Test Results

(A) Non-Serviced Vehicles				(B)	Serviced Vehicles			
Idle Test					Idle Test			
VEH	Results			No.	Idle Test Results		Post-Service Idle Test	
Limits	250	4.0		Limits	250	4.0	250	4.00
	HC	CO			HC	CO	HC	CO
1227	81	.11	Controlled	*1212	(9999)	(10.96)	(910)	2.84
1291	(360)	3.45		--	--	--	527	2.30
1254	182	1.33		1225	(580)	2.11	169	3.49
1217	215	(4.59)		1228	(268)	(4.84)	141	.16
1258	117	2.68		1238	(294)	3.91	102	.62
1303	156	3.25		1272	(521)	(5.39)	151	3.18
1289	125	1.48		1275	(437)	(9.63)	218	1.47
				1315	(307)	(6.16)	206	.05
Avg	176	2.41		Avg	401	5.34	49	1.29
Limits				Limits	700	5.0	700	5.0
1202	194	.07	Uncontrolled	1209	(9999)	(10.96)	(1576)	(5.53)
1207	343	4.08		1229	(800)	(7.33)	587	(6.72)
1255	387	4.20		--	--	--	459	2.90
1262	461	3.44		1230	(1032)	(10.24)	(784)	(5.08)
1213	311	(5.97)		1260	(1231)	(5.53)	(2246)	4.22
1236	503	(6.80)		--	--	--	527	3.43
1218	534	(8.41)		1273	504	(8.95)	360	4.04
1285	401	(6.36)		1281	(722)	(5.24)	(926)	(10.09)
				--	--	--	(733)	(6.44)
				1297	(831)	(9.93)	407	1.93
				1314	(853)	(9.09)	(735)	3.24
Avg	392	4.92		Avg	2886	8.69	697	3.84
Avg all Vehicles	292	3.75		Avg all Vehicles	1892	7.35	470	2.92

( ) = Values exceeding limits

*Vehicle 1212 is an uncontrolled car. Averages were corrected to reflect this.

Table 7-28. Idle Mode Inspection Test, Test Effectiveness/Service Costs/Repair Action

TV No.	Emission Reductions Volumetric Concentrations (PPM) HC	CO	NO_x	Repair Action	Service Costs
	CONTROLLED				
*1212	A 818	3.13	3	2,3,4,5,10	181.25
1225	C 199	.33	536	2,3,4,5,6,7(A) 9	78.68
1228	A 142	3.97	(891)	2,3,4,5	29.23
1238	D 134	4.78	(1341)	3,	27.00
1272	D 337	.92	(125)	3,4,	10.63
1275	A 119	1.89	(382)	2,3,4,5	25.10
1315	A 65	1.41	51	2,3,4,5	33.04
Avg	166	2.22	555		33.95
	UNCONTROLLED				
No.	HC	CO	NO_x		
1209	B 2944	.14	(886)	2,3,4,5,6	45.70
1229	D 140	(3.30)	1674	3,6,	32.14
1230	B 225	2.60	(849)	2,3,4,5,6	59.45
1260	D 192	1.24	(73)	2,3,4,	8.80
1273	E 88	1.77	(773)	2,3,4,	6.50
1281	A 90	.05	605	2,3,4,5,	23.20
1297	C 271	1.48	234	2,3,4,5,7(A) 9	55.36
1314	B 134	3.70	(899)	2,3,4,5,6	72.14
Avg	545	1.94	666		53.84
Avg, All	393	2.05	622		46.65

( ) = Values exceeding limits

*Vehicle 1212 is an uncontrolled car. Averages were corrected to reflect this.

Table 7-29. Idle Mode Inspection Test Repair Action Code

Code No.	Repair/Adjustment Action
1	Inspect/Test and Certify Compliance
2	Adjust Engine RPM
3	Adjust Idle Mixture
4	Adjust Ignition Timing/Dwell
5	Repair Ignition Sys/Replace Components
6	Repair/Replace Carburetor
7	Emission Control System Repair/Replace
(A)	PCV - Crankcase Ventilation
(B)	Exhaust Control
8	Heat Riser Repair
9	Air Cleaner Replacement
10	Value Repair

The available emission changes of the set of five vehicles as measured by seven-mode testing is:

	HC	CO	NO_x
Increase			614
Decrease	233	2.09	

Three vehicles had carburetor repair or replacement in addition to ignition system maintenance and adjustments; all vehicles increased substantially in NO_x values while decreasing in HC and CO; as a result of the maintenance one vehicle, a 63 VW, had a significant improvement in HC in spite of an apparent valve failure. This VW was not selected for major maintenance. The other two vehicles in the group had Idle Mode HC and CO values slightly in excess of Idle Mode limits during

Table 7-30. Emission Changes Versus Costs

VOLUMETRIC CONCENTRATIONS

No.	Test Vehicles	Pre-Test Vehicle Baseline			Post-Test Vehicle Baseline			Costs
	Failed/Service	HC	CO	NO_x	HC	CO	NO_x	$
7	Controlled	402	3.27	1541	236	1.05	1894	33.95
8	Uncontrolled	1076	4.49	975	531	3.20	1082	53.84
15	Average	806	4.00	1202	413	2.34	1407	46.65

No.	Test Vehicles	Pre-Test Vehicle Baseline			Post-Test Vehicle Baseline			Costs
	Passed/No Service	HC	CO	NO_x	HC	CO	NO_x	$
7	Controlled	203	1.10	1953	-	-	-	-
8	Uncontrolled	485	2.52	1590	-	-	-	-
15	Average	353	1.86	1759	-	-	-	-
All Vehicles		580	2.93	1481	-	-	-	-

AVERAGE: REDUCTIONS VERSUS COSTS

No.	Test Vehicles	HC	CO	NO_x	Service Costs
7	Controlled	166	2.22	(353)	33.95
8	Uncontrolled	545	1.29	(107)	53.84
15	All Serviced Vehicles	393	1.66	(205)	46.65
15	Non-Serviced All Vehicles	197	Assumed to be -0- .82	(14)	23.33

( ) Indicates Increase After Service

Table 7-31. Emission Changes Versus Costs

GRAMS PER MILE								
No.	Test Vehicles	Pre-Test Vehicle Baseline			Post-Test Vehicle Baseline			Costs
	Failed/Service	HC	CO	NO_x	HC	CO	NO_x	$
7	Controlled	5.21	79.25	5.86	3.08	19.73	7.08	33.95
8	Uncontrolled	7.73	92.87	3.26	5.78	65.51	3.61	53.84
15	Average	6.72	87.42	4.30	4.70	47.19	5.00	46.65

No.	Test Vehicles	Pre-Test Vehicle Baseline			Post-Test Vehicle Baseline			Costs
	Passed/No Service	HC	CO	NO_x	HC	CO	NO_x	$
7	Controlled	2.50	26.02	6.88	-	-	-	-
8	Uncontrolled	5.80	57.82	5.37				
15	Average	4.26	42.98	6.07	-	-	-	-
All Vehicles		5.49	65.20	5.19	-	-	-	-

AVERAGE: REDUCTIONS VERSUS COSTS

No.	Test Vehicles	HC	CO	NO_x	Service Costs
7	Controlled	2.13	59.52	(1.22)	33.95
8	Uncontrolled	1.95	27.36	(0.35)	53.84
15	All Serviced Vehicles	2.02	40.23	(0.70)	46.65
	Non-Serviced All Vehicles	Assumed to be -0- .96	20.11	(0.34)	-

( ) Indicates an increase after service.

the post-service idle tests; however, they were accepted on the basis of their improvement over initial test failures. The net emission changes for the group of three is:

	HC	CO	NO_x
Increase			871
Decrease	1101	2.14	____
Average	367	0.71	(290)

Two vehicles which had PCV valve maintenance and air cleaner replacement in addition to ignition, carburetion maintenance and adjustments, improved substantially in HC, CO, and NO_x. The emission change of the two is:

	HC	CO	NO_x
Decrease	235	0.90	385
Average	117	0.45	192

Four vehicles were adjusted only; two for idle speed, mixture and timing, one mixture and timing, and one mixture only. All vehicles passed the post-service idle test. Two required two trips to the service facility before acceptance. All of the vehicles improved in HC and CO while increasing in NO_x.

Average change in this group is as follows:

	HC	CO	NO_x
Decrease	200	0.91	33
Average	50	0.23	8

One vehicle had carburetor repair and adjustment and improved in HC and CO while increasing considerable in NO_x.

	HC	CO	NO_x
Increase			773
Decrease	88	1.77	

Total values for all vehicles within the Idle group are included in the accompanying tables.

7.4.2.2 Conclusions

Table 7-31 describes Idle operations test flow for controlled and uncontrolled vehicles. The table includes initial inspection test performed at the Northrop test facility and the post-service inspection. Inspection values recorded by the repair station on the Idle test data form have been entered under the test, adjust, and repair columns. Instructions supplied to the garage with each vehicle requested that they inspect the vehicle as received and prior to attempting adjustment, and to record the data. The instructions then directed that adjustments of idle speed, mixture, and ignition timing be accomplished to bring the vehicle into limits and that the results of that practice be recorded. Those vehicles capable of being adjusted to limits were to be returned for retest with no further repair action. Repair was authorized for those vehicles not capable of being adjusted. After completion of repair and system adjustments, the garage was to record in the emission values. Table 7-32 includes the data as recorded by the garage and returned with the vehicle. The four, adjusted only, vehicles were accomplished at a nominal service cost with the exception of one which was $27.00. However, this high charge was due to the unusual amount of time required as a result of suspected equipment failures. Two vehicles were adjusted to within limits by the garage and should have been returned at that point; however, the garages did not follow instructions and continued with maintenance action. In one case the maintenance was excessive and not required to repair the suspected malfunction. These excess costs in addition to the large number of ignition and carburetor repair operations in the Idle service group tend to weigh the cost effectiveness on the expensive side; however, it should be recognized that this particular group of vehicles selected for service had a large number of high emitters as compared to other test mode service groups, the excessive repair costs can be attributed to not following instructions. Integrating the instructions with the data form may be an approach to improving garage controls.

Table 7-32. Idle Test Flow

			Inspection				Garage Inspection Test and Repair												Inspection			
			Test				Test				Adjust				Repair				Test			
			Idle		2500		Idle		2500		Idle		2500		Idle		2500		Idle		2500	
			HC	CO	HC	CO	HC	CO	HC	CO	HC	CO	HC	CO	HC	CO	HC	CO	HC	CO	HC	CO
Controlled	Limits HC 250 CO 4.0	1212	9999	10.96	1590	5.59	2000	7.5	400	4.5	1800	3.5	-	-	900	3.25	300	2.5	660	6.63	130	8.94
		1225	580	2.11	138	.94	500	2.5	100	.5	500	2.0	-	-	120	2.7	-	-	169	3.49	80	.70
		1228	268	4.84	174	3.91	200	2.5	100	2.0	200	2.5	-	-	200	2.5	-	-	141	.16	74	.64
		1238	294	3.91	138	1.13	75	2.5	25	.35	100	1.0	-	-	-	-	-	-	102	.62	56	.39
		1272	521	5.39	93	.24	1600	8.5	100	.4	220	3.0	180	.5	-	-	-	-	151	3.18	50	.21
		1275	437	9.63	89	1.05	420	7.5	80	1.6	350	7.5	-	-	240	2.5	-	-	218	1.47	83	1.03
		1315	307	6.16	57	.21	400	5.	70	.2	220	2.0	-	.1	215	.15	100	2.5	206	.05	61	.17
Uncontrolled	Limits HC 700 CO 5.0	1209	9999	10.96	4170	6.75	2000+	7.5+	2000+	7.5+	2000+	2.8	1000	4.5	-	-	-	-	1576	5.53	1072	4.47
		1229	800	7.33	112	.63	850	7.5+	200	1.5	950	7.5+	-	-	600/500	5./3.0	-/-	-/-	587/459	6.72/2.9	232/177	3.81/3.12
		1230	1032	10.24	434	4.06	1300	1.75	1200	6.0	1400	5.0	-	-	-	-	-	-	748	5.08	259	1.54
		1260	1047	5.53	1047	4.06	1250	7.0	1900	5	640	4.5	260	4.5	-	-	-	-	527	3.42	257	4.02
		1273	504	8.95	135	1.58	400	7.5+	20	.5	300	2.2	100	.5	-	-	-	-	360	4.04	118	.50
		1281	722	5.24	400	1.96	1200	7.5	300	3.25	1500	4.75	-	-	-	-	-	-	926/535	10./5.6	171/203	3.5/3.01
		1297	831	9.93	1145	1.79	1300	7.5	1800	2.5	9.75	7.5	900	6.0	650	4.5	-	-	407	1.93	261	2.14
		1314	853	9.09	426	5.41	2000	6.5	1000	4.0	1600	3.0	1200	3.0	700	5.5	300	2.5	735	3.24	395	1.47

7.4.3 Diagnostic Inspection Test

Thirty vehicles were selected for Diagnostic Inspection testing procedures, fourteen controlled vehicles equipped with exhaust emission control systems and sixteen uncontrolled vehicles. Each vehicle was tested with seven-mode hot cycles to establish baseline emission values prior to testing by Diagnostic Mode test procedures. Diagnostic Mode test limits were established at levels sufficient to fail 50 percent of the controlled and uncontrolled vehicles. Vehicles determined to have failed the diagnostic emission test were subjected to a detailed systems condition diagnosis to determine the probable cause of failure and provide specific repair directions to the selected service facility. When service operations were completed, the vehicle was returned to the test facility and retested using the diagnostic test procedure. Vehicles found not to meet the established limit were re-diagnosed and recycled to the station for further maintenance as required. When the test vehicle was found to be in compliance, an additional seven-mode hot cycle test was performed to establish post-test baseline values for comparison with the pre-test baseline to evaluate changes in emissions.

Table 7-33 lists the pre- and post-test baseline emission values of controlled and uncontrolled vehicles selected for service. Emission averages are shown for controlled, uncontrolled, and all vehicles. Table 7-34 identifies the pre- and post-test values in grams per mile. Pretest data of vehicles not selected for service is included in Table 7-35.

Initial Diagnostic Mode test results for vehicles not receiving service are listed in Table 7-36. Table 7-37 lists the initial test results, and the post-service test results for vehicles receiving service. Test values in parenthesis () indicates emission values exceeding limits.

Test effectiveness/service costs and repair actions are included in Table 7-38.

Test effectiveness as listed is the net change (increase or decrease), in each emission value for each vehicle including group averages. Emission increases are noted in parentheses. Individual service costs and averages are listed for controlled, uncontrolled, and all vehicles combined. Repair actions are coded with a code description appearing in Table 7-39. Tables 7-40 and 7-41 identify emission changes versus service costs and average reductions versus costs.

Table 7-33. Controlled/Uncontrolled Vehicles Exceeding Limits and Selected for Service-Emissions in Concentrations Volumetric/Concentrations

CONTROLLED									
Test Vehicle				Pre-Test Vehicle Baseline 7-Mode Hot Cycles			Post-Test Vehicle Baseline 7-Mode Hot Cycles		
No.	Yr.	Make	Mileage	HC	CO	NO_x	HC	CO	NO_x
1204	68	CHRY	53,979	217	2.18	1,359	346	2.29	1,349
1205	68	VW	31,330	336	2.45	1,349	288	1.61	1,490
1232	66	OLDS	97,358	299	0.94	1,838	260	0.44	1,729
1241	66	MERG	35,293	394	1.44	1,517	251	1.06	1,168
1244	69	FORD	18,138	323	1.36	2,592	264	1.45	2,324
1261	69	CHEV	17,918	304	2.19	1,980	203	0.71	1,805
1296	67	FORD	38,703	337	1.64	1,762	263	1.31	1,400
Emission Averages				316	1.74	1,771	267	1.26	1,509
UNCONTROLLED									
1201	64	CHEV	44,595	771	3.40	1,931	480	1.66	1,328
1224	64	PONT	105,919	483	4.42	663	332	3.70	835
1236	65	COMET	51,288	559	8.05	612	656	5.55	964
1263	64	CHEV	67,493	619	6.53	306	482	2.06	1,443
1270	64	MERC	77,550	1,486	1.98	981	373	2.84	850
1309	59	CHEV	95,034	829	1.37	1,549	476	3.57	417
1316	63	PLY	82,249	644	2.52	1,840	341	0.81	1,601
1318	64	CHEV	71,564	1,002	5.32	588	733	1.02	1,061
Emission Average				799	4.20	1,059	484	2.65	1,062
Average All Vehicles				574	3.05	1,391	383	2.00	1,317

Table 7-34. Controlled/Uncontrolled Vehicles Exceeding Limits and Selected For Service in Grams Per Mile

CONTROLLED

Test Vehicle				Pre-Test Vehicle Baseline 7-Mode Hot Cycle			Post-Test Vehicle Baseline 7-Mode Hot Cycle		
No.	Yr.	Make	Mileage	HC	CO	NO_x	HC	CO	NO_x
1204	68	CHRY	53,979	3.12	58.86	5.38	4.97	61.83	6.46
1205	68	VW	31,330	3.11	42.58	3.64	2.11	27,98	4.08
1232	66	OLDS	97,358	3.79	22.39	6.75	3.29	10.47	7.15
1241	66	MERC	35,293	4.56	31.29	5.07	2.90	23.03	3.75
1244	69	FORD	18,138	4.09	32.39	9.15	3.34	34.53	8.82
1261	69	CHEV	17,918	3.51	47.59	6.63	2.34	15.42	6.88
1296	67	FORD	38,773	3.90	35.64	5.83	3.04	28.46	4.48
Emission Averages				3.73	38.68	6.06	3.14	28.82	5.95
UNCONTROLLED									
1201	64	CHEV	44,595	7.92	65.65	5.45	5.93	32.05	3.96
1224	64	PONT	105,919	6.58	113.06	2.57	4.52	94.64	3.80
1236	65	COMET	51,288	6.16	155.44	1.76	6.74	107.16	2.69
1263	64	CHEV	67,493	8.42	167.03	1.20	6.56	52.69	5.97
1270	64	MERC	77,550	21.37	53.46	3.88	5.36	77.69	3.60
1309	59	CHEV	95,034	9.39	29.39	5.04	5.43	76.59	1.36
1316	63	PLY	82,249	6.62	48.65	5.58	3.50	15.63	4.70
1318	64	CHEV	71,564	12.71	126.73	2.19	9.30	24.29	3.84
Emission Averages				9.84	94.92	3.45	5.79	60.09	3.74
AVERAGES FOR ALL CARS SERVICED									
All Cars Services				6.98	68.67	4.66	4.55	45.49	4.77

Table 7-35. Controlled/Uncontrolled Vehicles Not Exceeding Limits and Not Selected for Service

Test Vehicle				Pre-Test Baseline Concentrations			Pre-Test Baseline Grams Per Mile		
No.	Yr.	Make	Mileage	HC	CO	NO_x	HC	CO	NO_x
CONTROLLED									
1227	70	PLY	9,397	187	1.07	1,840	2.16	23.24	5.75
1291	68	OPL	36,959	326	2.16	1,349	1.84	22.99	2.15
1254	68	DODGE	45,099	239	1.67	1,394	3.03	39.78	5.14
1217	67	RAM	46,771	343	0.87	1,763	3.17	15.12	4.59
1258	68	TOY	24,053	182	1.73	1,437	1.60	28.64	3.67
1303	66	CAD	52,907	97	0.92	918	1.39	24.84	3.76
1289	67	CHEV	53,471	304	2.80	1,211	4.14	71.62	4.80
Emission Average				240	1.60	1,416	2.48	32.32	4.27
UNCONTROLLED									
1202	57	CHEV	64,338	495	2.86	1,276	5.72	62.15	4.29
1207	64	PLY	50,109	517	3.88	1,417	5.31	74.91	3.96
1255	65	MUST	68,127	694	4.49	825	7.13	86.69	2.38
1262	61	CORV	60,155	796	2.82	910	6.87	45.75	2.22
1213	64	RAM	55,322	424	1.35	1,854	4.90	29.33	6.22
1249	57	FORD	68,828	577	6.53	553	7.32	155.44	1.95
1218	60	PONT	54,156	351	0.81	2,184	4.78	20.71	8.63
1285	65	BUICK	93,697	466	2.86	1,148	5.39	62.15	3.87
Emission Average				540	3.65	1,270	5.92	67.14	4.19
Average All Vehicles				400	2.69	1,338	4.31	50.89	4.22

Table 7-36. Controlled/Uncontrolled Inspection Test Results
Vehicles Not Receiving Service

CONTROLLED	Limits	300	4.0	250	5.5	250	2.5	-	2000
	Veh	Idle		60MDL	/FL	50MDH	8HP		Decel
	No.	HC	CO	HC	CO	HC	CO	NO_x	HC
	1227	95	.43	137	4.02	140	.24	2908	822
	1291	121	1.26	207	2.10	214	.93	3931	589
	1254	176	2.66	87	2.52	57	.17	2150	1804
	1217	161	2.66	108	2.98	92	.09	2105	1070
	1258	70	1.60	44	3.31	39	.16	2575	629
	1303	147	1.75	93	(5.64)	31	.30	498	488
	1289	171	1.84	183	(5.62)	101	1.14	577	1300
	Avg.	134	1.74	123	3.74	96	.43	2106	886
UNCONTROLLED	Limits	700	7.0	400	5.5	500	3.5	-	-
	1202	538	516	291	6.97	338	3.24	1456	1455
	1207	396	6.75	119	1.93	221	3.18	1496	8501
	1255	598	(7.53)	255	5.19	332	3.04	1569	9114
	1262	(1535)	6.01	355	4.91	449	.64	2512	3120
	1213	444	3.51	249	4.01	257	1.32	2352	9999
	1249	542	(10.34)	(690)	2.05	447	(4.09)	1016	9999
	1218	395	1.75	192	4.43	263	.43	3484	9999
	1285	409	5.31	162	3.22	257	(4.30)	774	8621
	Avg.	607	5.79	2.89	4.08	320	2.53	1832	7601
	Avg.	386	3.90	2.11	3.92	214	1.55	1960	4467

( ) = Values Exceeding Limits

Table 7-37. Controlled/Uncontrolled Inspection Test/ Post-Service Results

CONTROLLED																
	Diagnostic Test Limits/Results								Post-Service Diagnostic Test Limits/Results							
Limits	300	4.0	250	5.5	250	2.5	-	2000	300	4.0	250	5.5	250	2.5	-	2000
Veh. No.	Idle		60 MPH/FL		50 MPH	8 HP		Decel.	Idle		60 MPH/FL		50 MPH		8 HP	Decel.
	HC	CO	HC	CO	HC	CO	NO	HC	HC	CO	HC	CO	HC	CO	NO	HC
1204	128	.80	142	3.13	170	(3.09)	1342	183	234	3.45	137	3.29	130	2.71	1618	(2190)
1205	284	(5.64)	223	4.80	176	1.14	2405	514	192	4.04	131	3.97	106	.79	3264	940
1232	222	3.29	126	2.92	(273)	.59	1629	952	203	3.61	(749)	.30	(849)	.25	1773	1040
									176	1.18	100	1.39	113	.14	1891	730
1241	156	2.02	156	2.19	140	.54	1736	(5771)	102	1.38	132	1.19	113	.36	1769	1332
1244	(378)	(5.44)	191	2.98	(393)	.29	3060	1559	204	3.84	160	4.40	201	.39	3398	(2247)
1261	(395)	(8.46)	196	5.17	167	1.32	2540	(9999)	252	(5.13)	164	(5.55)	138	.83	2682	(High)
									168	.96	188	(6.33)	173	1.18	2265	4002
1269	(382)	3.89	(275)	(6.31)	175	1.21	1709	557	277	(4.83)	(260)	(6.01)	208	1.00	1607	281
									183	1.70	239	(6.20)	148	.72	1885	216
Avg.	278	4.22	187	393	213	1.17	2060	2790	180	2.36	155	3.82	141	.90	2299	1665
UNCONTROLLED																
Limits	700	7.0	400	5.5	500	3.5	-	9000	700	7.0	400	5.5	550	3.5	-	-
1201	(990)	(10.21)	310	5.30	(795)	1.28	2856	2974	(779)	(8.14)	239	(5.14)	225	.89	2754	9999
									646	2.35	(422)	4.04	348	.73	2411	9999
1224	403	3.37	(1021)	(6.63)	(624)	(8.71)	2966	(9999)	155	1.55	251	(7.92)	282	(4.56)	644	349
									249	3.99	255	2.47	474	(7.12)	699	1123
									283	3.51	(1049)	(5.94)	388	(7.18)	760	2405
1236	410	(8.47)	212	.76	278	2.77	2061	8109	574	5.98	200	3.05	235	2.49	2066	4229
1263	409	5.01	376	(9.55)	380	(5.51)	261	8194	(856)	3.5	311	(6.55)	358	(4.26)	1011	9999
									(723)	2.88	(411)	(7.53)	393	2.82	1848	999
1270	(2474)	1.93	325	1.51	393	1.63	261	3321	549	6.20	92	2.43	88	1.40	1163	4673
1309	(2107)	.13	(478)	2.12	396	2.32	1952	1189	346	2.77	267	(5.60)	295	3.13	976	9999
1316	638	(10.58)	164	4.05	184	.72	-	(9999)	420	1.24	126	4.39	101	.37	3305	7720
1318	(731)	6.01	362	4.88	(580)	(6.61)	587	6821	367	.51	308	(8.55)	301	2.35	1324	386
	1020	5.71	406	4.35	454	3.69	1368	6326	489	3.18	359	1.07	269	2.56	1732	5051
Avg.		5.01	304	4.15	342	2.51	1691	3374	345	2.80	264	2.35	209	1.43	1997	3471

( ) = Values Exceeding Limits

Table 7-38. Test Effectiveness/Service Costs/Repair Action

CONTROLLED					
TV	Emission Reductions in Concentrations			Repair Action	Service Costs
No.	HC	CO	NO_x		
1204	(129)	.11	10	3, 4, 5, 9	18.36
1205	48	.84	(141)	4, 10	8.55
1232	39	.50	109	3, 4, 5, 6, 8	107.95
1241	143	.38	349	3, *	∅
1244	59	(.09)	268	3,	2.50
1261	101	1.48	175	2, 3, 4, 9 *	8.88
1296	74	.33	362	2, 3, 4, 9	19.20
Avg.	49	.48	162		23.65
UNCONTROLLED					
1201	291	1.74	603	2, 3, 4, 5, 6	45.65
1224	151	.72	(172)	3, 4, 5, 6	63.15
1236	(97)	2.50	(352)	4, 5	16.80
1263	137	4.47	(1137)	2, 3, 4, 5, 6	74.55
1270	1113	(4.86)	131	9, 11	148.60
1309	353	(2.50)	1132	4, 5, 7(A), 8	60.34
1316	303	1.71	239	2, 3, 4, 5, 6	33.40
1318	269	4.30	(588)	2, 3, 4, 5, 6	73.80
Avg.	315	1.55	(3)		64.60
Avg.	191	1.05	77.2		46.48

*Serviced by OLI Test Team

( ) = Increased after service

Table 7-39. Repair Action Code

Code No.	Repair/Adjustment Action
1	Inspect/Test and Certify Compliance
2	Adjust Engine RPM
3	Adjust Idle Mixture
4	Adjust Ignition Timing/Dwell
5	Repair Ignition Sys/Replace Components
6	Repair/Replace Carburetor
7	Emission Control System Repair/Replace
(A)	PCV - Crankcase Ventilation
(B)	Exhaust Control
8	Heat Riser Repair
9	Air Cleaner Replacement
10	Adjust Injector Fuel Pressure
11	Valve Repair

Table 7-40. Emission Changes Versus Costs - Volumetric Concentrations

No.	Test Vehicles	Pre-Test Vehicle Baseline			Post-Test Vehicle Baseline			Costs
	Failed/Service	HC	CO	NO_x	HC	CO	NO_x	$
7	Controlled	316	1.74	1771	267	1.26	1609	23.65
8	Uncontrolled	799	4.20	1059	484	2.65	1062	64.60
15	Average Total	574	3.05	1391	383	2.00	1317	46.48

No.	Test Vehicles	Pre-Test Vehicle Baseline			Post-Test Vehicle Baseline			Costs
	Passed/No Service	HC	CO	NO_x	HC	CO	NO_x	$
7	Controlled	240	1.60	1416	-	-	-	-
8	Uncontrolled	540	3.65	1270				
15	Average	400	2.69	1338	-	-	-	-
All Vehicles		487	2.87	1365	-	-	-	-

AVERAGE: REDUCTIONS VERSUS COSTS

No.	Test Vehicles	HC	CO	NO_x	Service Costs
7	Controlled	49	.48	162	23.65
8	Uncontrolled	315	1.50	3	64.60
15	All Serviced Vehicles	189	1.02	74	46.48
	Non-Serviced All Vehicles	Assumed to be -0- 95	.51	37	23.24

Table 7-41. Emission Changes Versus Costs - Grams Per Mile

No.	Test Vehicles	Pre-Test Vehicle Baseline			Post-Test Vehicle Baseline			Costs
	Failed/Service	HC	CO	NO_x	HC	CO	NO_x	$
7	Controlled	3.73	38.68	6.06	3.14	28.82	5.95	23.65
8	Uncontrolled	9.84	94.92	3.45	5.79	60.09	3.74	64.60
15	Average	6.98	68.67	4.66	4.55	45.49	4.77	46.48

No.	Test Vehicles	Pre-Test Vehicle Baseline			Post-Test Vehicle Baseline			Costs
	Passed/No Service	HC	CO	NO_x	HC	CO	NO_x	$
7	Controlled	2.48	32.32	4.27	-	-	-	-
8	Uncontrolled	5.92	67.14	4.19				
15	Average	4.31	50.89	4.22	-	-	-	-
All Vehicles		5.65	59.78	4.44	-	-	-	-

AVERAGE: REDUCTIONS VERSUS COSTS

No.	Test Vehicles	HC	CO	NO_x	Service Costs
7	Controlled	.58	9.86	.12	$23.65
8	Uncontrolled	4.12	26.58	(.28)	64.60
15	All Serviced Vehicles	2.47	18.78	(.09)	46.48
15	Non-Serviced	Assumed to be -0-			
	All Vehicles	1.24	9.39	(.05)	$23.24

( ) = Increased after service

7.4.4 Key-Mode Inspection Test

Thirty vehicles were selected for Key-Mode inspection testing, 12 controlled vehicles equipped with exhaust emission control systems and 18 uncontrolled vehicles. Each vehicle was tested with seven-mode hot cycle to establish baseline emission values prior to testing by the Key-Mode testing procedures. Key-Mode test limits were established at levels sufficient to fail 50 percent of the controlled vehicles and 50 percent of the uncontrolled. Vehicles determined to have failed were delivered to selected repair stations along with the Key-Mode report card for adjustments and system repair as determined by the station maintenance personnel. When service operations were completed, the vehicle was returned to the test facility and retested, using the Key-Mode procedure. Vehicles found not to meet the established limits were recycled to the station for further maintenance as required. When the test vehicle was found to be in compliance, an additional seven-mode hot cycle test was performed to establish post-test baseline values for comparison with the pre-test baseline to evaluate changes in emissions.

Table 7-42 lists the pre- and post-test baseline emission values of controlled and uncontrolled vehicles selected for service. Emission averages are shown for controlled, uncontrolled, and all vehicles. Table 7-43 identifies the pre- and post-test values in grams per mile. Pre-test data of vehicles not selected for service is included in Table 7-44.

Initial Key-Mode test results for vehicles not receiving service are listed in Table 7-45. Table 7-46 lists the initial test results, and the post-service test results for vehicles receiving service. Test values in parenthesis () indicate emission values exceeding limits.

Test effectiveness/service costs and repair actions are included in Table 7-47. Test effectiveness as listed, is the net change (increase or decrease) in each emission value for each vehicle including group averages. Emission increases are noted in parentheses. Individual service-costs and averages are listed for controlled, uncontrolled, and all vehicles combined. Repair actions are coded with a code description appearing in Table 7-48. Tables 7-49 and 7-50 identify emission changes versus service costs and average reductions versus costs.

Table 7-42. Controlled/Uncontrolled Vehicles Exceeding Limits and Selected for Service-Emissions in Volumetric Concentrations (PPM)

CONTROLLED									
Test Vehicle				Pre-Test Vehicle Baseline			Post-Test Vehicle Baseline		
No.	Yr.	Make	Mileage	HC	CO	NO_x	HC	CO	NO_x
1235	69	VW	27,262	1,147	1.18	1,367	1,168	1.62	944
1256	66	LINCOLN	62,346	165	2.21	853	184	1.84	925
1276	66	MERC		223	1.70	1,361	235	1.55	919
1283	70	CHEV	18,526	180	0.93	1,596	146	0.54	1,582
1312	66	PONT	65,099	146	2.25	949	229	1.24	1,553
1214	68	FORD	50,927	388	2.77	1,291	245	0.95	1,368
Emission Averages				375	2.01	1,236	368	1.29	1,215
UNCONTROLLED									
1234	64	VW	69,047	1,180	5.14	738	703	4.06	1,031
1239	64	VW	69,383	410	6.33	899	441	4.17	1,473
1242	64	FORD	75,216	816	5.29	255	469	7.59	199
1257	65	FORD	59,018	763	6.04	697	342	3.15	1,704
1268	62	CAD	68,623	364	4.34	608	234	3.47	728
1279	58	CHEV	82,685	568	4.46	678	366	0.76	1,967
1288	64	CORV	72,432	924	5.92	267	876	6.05	228
1294	62	VW	94,911	1,413	3.88	1,123	776	2.67	1,413
1305	62	OLDS	47,791	1,208	8.05	325	500	1.35	1,272
Emission Averages				849	5.49	621	523	3.69	1,112
Average All Vehicles				659	4.10	867	461	2.73	1,153

Table 7-43. Controlled/Uncontrolled Vehicles Exceeding Limits and Selected for Service in Grams Per Mile

CONTROLLED									
Test Vehicle				Pre-Test Vehicle Baseline			Post-Test Vehicle Baseline		
No.	Yr.	Make	Mileage	HC	CO	NO_x	HC	CO	NO_x
1235	69	VW	27,262	10.61	20.50	3.62	15.61	28.15	2.72
1256	66	LINCOLN	62,346	2.46	62.09	3.72	2.75	51.69	4.11
1276	66	MERC	76,870	2.82	40.49	5.01	2.98	36.92	3.38
1283	70	CHEV	18,526	2.45	23.78	5.73	1.98	13,80	5.97
1312	66	PONT	65,099	1.85	53.59	3.48	2.90	29.53	5.44
1214	68	FORD	50,927	4.92	89.80	4.72	3.10	22.62	4.71
Avg	67.5		50,171	4.18	48.37	4.38	4.89	30,45	4.39
UNCONTROLLED									
1234	64	VW	69,047	7.61	62.28	1.41	4.53	49.19	1.79
1239	64	VW	69,383	3.25	94.31	2.21	3.49	62.12	3.47
1242	64	FORD	75,216	7.05	85.82	0.68	4.05	123.13	0.46
1257	65	FORD	59,018	7.74	116.62	2.14	3.51	60.82	5.21
1268	62	CAD	68,623	5.44	121.93	2.90	3.50	97.49	3.26
1279	58	CHEV	82,685	7.20	106.24	2.29	4.64	18.10	6.64
1288	64	CORV	72,432	7.98	96.04	0.63	7.57	98.15	0.54
1294	62	VW	94,911	9.12	47.01	2.11	5.00	32.35	2.64
1305	62	OLDS	47,791	12.42	155.44	0.99	5.14	26.06	3.58
Avg	62.8		71,012	7.53	98.41	1.71	4.60	63.05	3.07
AVERAGE-ALL CARS									
All Cars Serv	64.7		62,676	6.19	78.39	2.78	4.72	50.01	3.60

Table 7-44. Controlled/Uncontrolled Vehicles Not Exceeding Limits and Not Selected for Service

CONTROLLED									
Test Vehicle				Pre-Test Baseline Volumetric Concentrations (PPN)			Pre-Test Baseline Grams Per Mile		
No.	Yr.	Make	Mileage	HC	CO	NO_x	HC	CO	NO_x
1210	69	CHEV		165	0.70	2,066	2.24	17.90	8.27
1219	70	DAT		315	0.86	2,725	2.49	12.81	6.46
1259	66	FORD		418	1.11	1,720	3.86	19.29	4.83
1280	69	DODGE		225	0.72	2,605	3.06	18.41	9.98
1222	67	FORD		185	0.39	1,974	2.52	9.97	7.82
1266	66	FORD		291	0.98	1,837	3.96	25.06	7.48
Emission Averages				266	0.79	2,154	3.02	17.24	7.47
UNCONTROLLED									
1307	66	CHEV		708	3.65	1,209	8.98	86.95	4.46
1220	61	PONT		487	3.35	834	5.66	72,80	2.88
1223	64	OLDS		561	3.72	1,025	7.11	88.61	3.91
1252	65	JEEP		634	3.22	1,559	7.24	69.08	5.08
1267	58	DODG		820	2.38	1,032	10.40	56.69	3.97
1251	60	RAMB		1,008	3.76	716	9.33	65.35	1.98
1271	56	BUICK		1,131	2.38	421	14.35	56.69	1.59
1295	50	FORD		1,148	3.23	859	11.96	63.20	2.69
1292	63	CHEV		873	2.75	1,493	11.07	65.51	5.73
Emission Average				819	3.16	1,016	9.57	69.43	3.59
Average All Vehicles				598	2.21	1,471	6.95	48.55	5.14

Table 7-45. Controlled/Uncontrolled Inspection Test Results
Vehicles Not Receiving Service

CONTROLLED	Limits	300	2.5	300	2.5	350	4.0
	Veh	Hi-Cruise		Low-Cruise		Idle	
	No.	HC	CO	HC	CO	HC	CO
	1210	115	0.09	138	0.10	177	2.42
	1219	113	0.08	177	0.22	177	2.16
	1259	129	0.56	181	0.95	56	1.29
	1280	116	0.72	113	0.18	197	1.59
	1222	92	0.11	106	0.09	108	1.14
	1266	109	0.52	163	0.63	129	2.55
	Avg.	112	0.34	145	0.36	140	1.85
	Limits						
UNCONTROLLED	1307	273	1.50	410	3.20	668	6.75
	1220	165	1.51	191	1.05	398	4.30
	1223	286	3.30	330	3.80	689	8.50
	1252	92	0.30	162	1.82	634	8.73
	1267	177	0.21	284	0.92	1270	10.97
	1251	218	1.17	406	3.22	963	9.57
	1271	296	1.04	411	2.21	357	2.26
	1295	117	0.53	243	2.79	1009	8.16
	1292	206	1.69	334	2.98	1024	9.72
	Avg.	203	1.25	307	2.44	779	7.66
	All Veh	167	0.89	242	1.61	523	4.34

Table 7-46. Controlled/Uncontrolled Inspection Test/Post-Service Test Results

( ) = Value Exceeds Established Limits

CONTROLLED												
	Key-Mode Inspection Test						Post-Service Key-Mode Inspection Test					
Limits	300	2.5	300	2.5	350	4.0						
	Hi-Cruise		Low-Cruise		Idle		Hi-Cruise		Low-Cruise		Idle	
No.	HC	CO	HC	CO	HC	CO	HC	CO	HC	CO	HC	CO
1235	288	1.27	(746)	1.41	(1549)	.98	272	(3.55)	(892)	1.01	(1403)	1.02
1256	30	.98	33	.92	(537)	(4.42)	48	1.31	48	.78	173	.09
1276	92	.88	130	1.09	138	(2.53)	114	.55	148	.92	195	2.19
1283	125	.12	183	.11	251	(5.22)	118	.13	173	.11	186	2.56
1312	86	1.21	87	1.48	83	(2.63)	75	.37	92	.86	107	2.27
1214	201	2.47	171	.50	292	(6.10)	122	.16	138	.15	158	2.10
Avg	137	1.15	225	.91	475	3.64	125	1.01	249	.63	370	1.71
UNCONTROLLED												
Limits	550	3.5	550	3.5	800	7.0	550	3.5	550	3.5	800	7.0
1234	153	2.22	288	3.52	829	4.52	96	1.54	175	2.01	684	(7.28)
							156	2.65	272	2.24	725	6.46
1239	140	.97	295	(7.79)	344	(7.27)	257	(5.0)	263	2.93	282	5.41
1242	378	(6.13)	(561)	(9.72)	(1339)	4.58	390	(8.08)	(593)	(9.17)	423	4.83
							264	(6.85)	402	(8.41)	466	4.35
1257	290	2.23	442	(4.49)	793	(10.95)	196	1.07	267	1.08	469	(9.07)
							242	.94	249	.65	937	(9.31)
							227	1.03	301	1.22	357	6.97
1268	278	(4.31)	273	2.69	275	4.83	191	3.25	229	2.47	157	1.61
1279	293	(3.39)	381	(4.56)	353	6.48	133	.18	339	2.79	272	1.68
1288	299	(7.10)	236	(6.18)	(862)	6.25	160	(5.27)	215	(6.46)	(1136)	(9.12)
1294	92	.26	191	1.63	(9999)	(10.97)	65	.14	199	.65	510	6.07
1305	425	(4.04)	683	(7.46)	(1334)	(10.94)	258	.42	295	.37	615	4.11
Avg	260	3.41	372	5.34	1792	7.42	203	2.46	292	3.11	533	5.87
Avg all vehicles	211	2.51	313	3.57	1076	5.91	172	1.88	275	2.12	468	4.21

Table 7-47. Test Effectiveness/Service Costs/Repair Action

CONTROLLED					
TV	Emission Reductions in Concentrations (ppm)			Repair Action	Service Costs
No.	HC	CO	NO_x		$
1235	(21)	(.44)	423	10	4.50
1256	(19)	.37	(72)	3, 7(A)	9.15
1276	(12)	.15	442	2, 3, 4, 6	34.41
1283	34	.39	14	3	5.50
1312	(83)	1.01	(604)	3, 4	15.50
1214	143	2.82	(77)	4, 6	20.40
Avg Reduction	7	.72	(21)		14.91
UNCONTROLLED					
No.	HC	CO	NO_x		
1234	477	1.08	(293)	3, 6, 11	32.95
1239	(31)	3.84	(574)	3, 4	14.40
1242	347	(2.30)	56	2, 3, 4, 5, 6, 9, 12	142.62
1257	421	2.89	(1007)	2, 3, 4, 5, 6	38.50
1268	130	.87	(120)	3, 6	23.50
1279	202	3.70	(1289)	2, 3, 4, 6	36.30
1288	48	(.13)	39	2, 3, 4, 5, 6	81.44
1294	637	1.21	(290)	2, 3, 4, 5, 6	26.35
1305	708	6.70	(947)	2, 3, 4, 5, 6	83.15
Avg. Reduction	327	1.98	(492)		53.47
Avg All Cars	199	1.48	(304)		38.05

( ) Indicates an Increase After Service

Table 7-48. Repair Action Code

Code No.	Repair/Adjustment Action
1	Inspect/Test and Certify Compliance
2	Adjust Engine RPM
3	Adjust Idle Mixture
4	Adjust Ignition Timing/Dwell
5	Repair Ignition Sys/Replace Components
6	Repair/Replace Carburetor
7	Emission Control System Repair/Replace
(A)	PCV - Crankcase Ventilation
(B)	Exhaust Control
8	Heat Riser Repair
9	Air Cleaner Replacement
10	No Service Diagnosis Only
11	Repair Injector Nozzle
12	Grind Valves

Table 7-49. Emission Changes Versus Costs

(VOLUMETRIC CONCENTRATIONS)

Serviced Vehicles

No.	Test Vehicles	Pre-Test Vehicle Baseline			Post-Test Vehicle Baseline			Costs
	Failed/Service	HC	%CO	NO_x	HC	%CO	NO_x	$
6	Controlled	375	2.01	1236	368	1.29	1215	14.91
9	Uncontrolled	849	5.49	621	523	3.69	1112	53.47
15	Average	659	4.10	867	461	273	1153	38.05

Non-Serviced Vehicles (Grams per Mile)

No.	Test Vehicles	Pre-Test Vehicle Baseline			Post-Test Vehicle Baseline			Costs
	Passed/No Service	HC	CO	NO_x	HC	CO	NO_x	$
6	Controlled	266	.79	2154	-	-	-	-
9	Uncontrolled	819	3.16	1016	-	-	-	-
15	Average	598	2.21	1471	-	-	-	-
All Vehicles		630	3.19	1159	-	-	-	-

AVERAGE: REDUCTIONS VERSUS COSTS

(VOLUMETRIC CONCENTRATIONS)

No.	Test Vehicles	HC	CO	NO_x	Service Costs
6	Controlled	7	.72	(21)	$14.91
9	Uncontrolled	327	1.98	(492)	$53.49
15	All Serviced Vehicles	199	1.48	(304)	$38.05
15	Non-Serviced	Assumed to be		-0-	-0-
30	All Vehicles	99.5	.74	(152)	$19.03

( ) Indicates Increase After Testing

Table 7-50. Emission Changes Versus Costs

(Grams Per Mile)

Serviced Vehicles

No.	Test Vehicles	Pre-Test Vehicle Baseline			Post-Test Vehicle Baseline			Costs
	Failed/Service	HC	CO	NO_x	HC	CO	NO_x	$
6	Controlled	4.18	48.37	4.38	4.89	30.45	4.39	14.91
9	Uncontrolled	7.53	98.41	1.71	4.60	63.05	3.07	53.47
15	Average	6.19	78.39	2.78	4.72	50.01	3.60	38.05

Non-Serviced Vehicles (Grams Per Mile)

No.	Test Vehicles	Pre-Test Vehicle Baseline			Post-Test Vehicle Baseline			Costs
	Passed/No Service	HC	CO	NO_x	HC	CO	NO_x	$
6	Controlled	3.02	17.24	7.47	-	-	-	-
9	Uncontrolled	9.57	69.43	3.59				
15	Average	6.95	48.55	5.14	-	-	-	-
All Vehicles		6.57	63.47	3.96	-	-	-	-

AVERAGE: REDUCTIONS VERSUS COSTS

No.	Test Vehicles	HC	CO	NO_x	Service Costs
6	Controlled	(0.70)	17.92	(0.15)	14.91
9	Uncontrolled	2.93	35.36	(1.24)	53.47
15	All Serviced Vehicles	1.48	28.38	(0.80)	38.05
15	Non-Serviced	Assumed to be -0-			
29	All Vehicles	0.74	14.19	(0.40)	$19.03

( ) Indicates Increase After Service

7.4.5 Maintenance Cost Analysis

The direct charges incurred to perform the required maintenance included both labor and replacement parts costs. For each test regime, two tables of cost data are presented. The first tabulates costs by each test vehicle, the second summarizes and highlights salient cost information such as high and low extremes of labor and parts costs, average labor and parts costs, and total expenditures. A summary cost comparison table showing all four test regimes is also presented.

a. Certificate of Compliance Costs - Table 7-51 tabulates all costs incurred as direct charges to the respective test vehicles. Table 7-52 shows the extremes of labor and parts costs, and also the calculated average labor and parts cost per serviced vehicle. It should be noted that total parts and labor charges differ from total Northrop cost due to fleet discount price offered in some cases by the participating maintenance facilities. For the Certificate of Compliance testing, the average cost per vehicle is $7.06. This cost would have been borne by the owner and includes $5.83 for labor and $1.23 for parts. The total cost to Northrop was $180.67 for 27 vehicles.

b. Idle Test Costs - Table 7-53 tabulates all costs incurred by vehicles undergoing the Idle Test procedure. Table 7-54 shows the cost breakdown for individual categories such as high and low extremes of both labor and parts charges. The total discounted cost to Northrop for 15 test vehicles amounted to $688.78. For this test regime the average cost to the vehicle owner would be $46.65 which is comprised of $29.90 for labor and $16.75 for parts.

c. Key Mode Test Costs - Table 7-55 presents the expenditures for each test vehicle, both controlled and uncontrolled. Table 7-56 shows the average costs incurred along with the high and low extremes for the major cost items of labor and parts. Total Northrop cost for the Key Mode test regime was $561.37 of which $350.20 was for labor, the remainder for parts and state tax. The average cost to the 14 vehicle owners would have been $39.04 which included $23.39 for labor and $15.65 for parts.

Table 7-51. Certificate of Compliance Service Cost to Car Owner

Car No.	Labor Cost	Parts Cost (W/O Tax)	Total Cost W/O Parts Tax
Controlled			
1211	$ 7.50		$ 7.50
1221	6.00		6.00
1233	12.60		12.60
1243	8.00	$2.55	10.55
1246	6.80		6.80
1264	5.00	1.85	6.85
1269	12.60		12.60
1287	7.50	4.95	12.45
1299	5.00	0.70	5.70
1308	8.10		8.10
1313	5.00		5.00
1317	4.50		4.50
		Sub-total	$98.65
		Average/Vehicle	8.22
Uncontrolled			
1203	8.10	1.89	9.99
1206	3.10		3.10
1215	7.65	5.25	12.90
1226	3.10		3.10
1240	3.10		3.10
1245	9.00	3.38	12.38
1248	No Smog Device		0
1253	8.10	1.89	9.00
1265	5.00		5.00
1274	3.00		3.00
1277	2.50		2.50
1293	2.00	1.69	3.69
1298	No Smog Device		0
1301	3.10	2.55	5.65
1302	6.00	4.95	10.95
1304	3.00		3.00
1310	2.00		2.00
1319	No Smog Device		0
		Sub-total	$90.35
		Average/Vehicle	6.02
		TOTAL	$189.00

Table 7-52. Certificate of Compliance Costs

27 Cars Serviced			
3 Cars had no smog equipment			
30 Cars completed			
High Labor	$12.60		
Low Labor	2.00		
Total Labor		$157.35	
Average Labor/Car			$5.83
High Parts	$ 4.95		
Low Parts	0		
Total Parts		$ 31.65 + tax	
Average Parts/Cars			$1.23
Total Parts and Labor		$189.00	
Total Average Cost/Car to Owner			$7.06
TOTAL NORTHROP COST		$180.67	

Table 7-53. Idle Test Service Cost to Car Owner

Car No.	Labor Cost	Part Cost W/O Tax	Total Cost W/O Parts Tax
Controlled			
1225	$ 42.45	$36.23	$ 78.68
1228	14.95	14.28	29.23
1238	27.00	0	27.00
1272	8.00	2.63	10.63
1275	17.60	7.50	25.10
1315	19.20	13.84	33.04
		Sub-total	$203.68
		Average/Vehicle	33.95
Uncontrolled			
1209	33.00	12.70	45.70
1229	13.50	18.64	32.14
1212	152.95	28.30	181.25
1230	27.00	32.45	59.45
1260	8.80	0	8.80
1273	6.50	0	6.50
1281	15.50	7.70	23.20
1297	20.35	35.01	55.36
1314	42.00	30.12	72.12
		Sub-total	$484.52
		Average/Vehicle	53.84
		TOTAL	$688.20

Table 7-54. Idle Test Costs

15 Cars Completed			
High Labor	$152.95		
Low Labor	6.50		
Total Labor		$448.80	
Average Labor/Car			$29.90
High Parts	$ 36.23		
Low Parts	0		
Total Parts		$239.40 + tax	
Average Parts/Car			$16.75
Total Parts and Labor		$688.20	
Total Average Cost/Car			$46.65
TOTAL NORTHROP COST		$688.78	

Table 7-55. Key Mode Test Service Cost to Car Owner

Car No.	Labor Cost	Part Cost W/O Tax	Total Cost W/O Parts Tax
Controlled			
1214	$ 19.20	1.20	$ 20.40
1235	4.50	0	4.50
1256	6.50	2.65	9.15
1276	23.50	13.91	37.41
1283	5.50	0	5.50
1312	14.50	1.00	15.50
		Sub-total	92.46
		Average/Vehicle	15.41
Uncontrolled			
1234	22.80	10.15	32.95
1239	14.40	0	14.40
1242	103.50	39.12	142.62
1257	23.00	15.50	38.50
1268	18.00	7.50	25.50
1279	27.00	9.30	36.30
1294	13.80	12.55	26.35
1288	12.50	68.94	81.44
1305	41.50	41.65	83.15
		Sub-Total	481.21
		Average/Vehicle	53.47
		TOTAL	$573.67

Table 7-56. Key Mode Test Costs

15 Cars Completed			
High Labor	$103.50		
Low Labor	4.50		
Total Labor		$350.20	
Average Labor/Car			$23.39
High Parts	$ 68.94		
Low Parts	0		
Total Parts		$223.47 + tax	
Average Parts/Car			$15.65
Total Parts and Labor		$573.67	
Total Average Cost/Car			$39.84
TOTAL NORTHROP COST		$561.37	

d. Diagnostic Test Costs - Table 7-57 identifies the labor and parts costs for each test vehicle that received Diagnostic service. Table 7-58 tabulates the average costs and the high and low labor and parts cost. For this test regime, Northrop paid $661.27 for diagnosis of 15 vehicles. The average motorist cost would have been $46.48 of which $28.15 would have been for labor and $18.33 for parts.

7.4.5.1 Cost Summary and Comparison

Table 7-59 provides a summary of labor and parts costs by test regimes. This preliminary cost data analysis shows that Certificate of Compliance is by far the least costly program in view of vehicle owner expenditures. Conversely, the Idle Test and Diagnostic regimes vehicles incur the highest charges with Key Mode not significantly lower in cost to the owner. It is interesting to note that for all test regimes except Certificate of Compliance, the controlled vehicle charges were significantly lower (40 to 70 percent) than uncontrolled vehicles within the same test regime. For the Certificate of Compliance, the opposite was true; the controlled vehicles experienced a higher average cost although the absolute magnitude of the difference is not so dramatic as those exhibited by the other three test regimes.

Table 7-57. Diagnostic Test Service Cost to Car Owner

Car No.	Labor Cost	Part Cost W/O Tax	Total Cost W/O Parts Tax
Controlled			
1204	$14.40	$ 4.36	$ 18.76
1205	8.55	0	8.55
1232	56.70	51.25	107.95
1241	0	0	0
1244	2.50	0	2.50
1261	5.60	3.28	8.88
1296	14.40	4.80	19.20
		Sub-total	$165.84
		Average/Vehicle	23.65
Uncontrolled			
1201	38.70	6.95	45.65
1224	40.45	22.70	63.15
1236	8.50	8.30	16.80
1263	29.75	44.80	74.55
1270	95.50	53.10	148.60
1309	34.20	26.14	60.34
1316	28.65	4.75	33.40
1318	42.30	31.50	73.80
		Sub-total	$516.29
		Average/Vehicle	64.60
		TOTAL	$682.13

Table 7-58. Diagnostic Test Costs

15 Cars Completed			
High Labor	$95.50		
Low Labor	0		
Total Labor		$420.20	
Average Labor/Car			$28.15
High Parts	$53.10		
Low Parts	0		
Total Parts		$261.93 + tax	
Average Parts/Car			$18.33
Total Parts and Labor		$682.13 + tax	
Total Average Cost/Car			$46.48
TOTAL NORTHROP COST		$661.27	

Table 7-59. Cost Summary and Comparison

Cost Category	Certificate of Compliance	Idle Test	Key Mode Test	Diagnostic Test
Labor Charges				
Highest Cost any Vehicle	$ 12.60	$152.95	$103.50	$ 95.50
Lowest Cost any Vehicle	2.00	6.50	4.50	-0-
Average Cost per Vehicle	5.83	29.90	23.39	28.15
Total Program Cost	157.35	448.80	350.20	420.20
Parts Charges				
Highest Cost any Vehicle	4.95	36.23	68.94	53.10
Lowest Cost any Vehicle	-0-	-0-	-0-	-0-
Average Cost per Vehicle	1.23	16.75	15.65	18.33
Total Program Cost	31.65*	239.40*	223.47*	261.93*
TOTAL PARTS AND LABOR COSTS	$189.00*	$688.20*	$573.67*	$682.13*
TOTAL AVERAGE COST TO OWNER	7.60	46.65	39.04	46.48
Controlled Vehicle Owner	8.22	33.95	15.41	23.65
Uncontrolled Vehicle Owner	6.02	53.84	53.47	64.60
GRAND TOTAL NORTHROP COSTS				$2,092.09

*Plus Tax

SECTION 8
LEARNING PHASE RESULTS

The initial phase of the pilot study was dedicated to conducting a preliminary evaluation of the four test regimes by processing a smaller sample lot of 120 vehicles. This learning phase has been fully described in the preceding paragraphs. For convenience, the salient features of this significant milestone are summarized and discussed in the ensuing paragraphs. The procedures instituted for vehicle selection and scheduling are discussed. Data management practices are described and are followed by a discussion of the participation and cooperation of vehicle maintenance facilities. A brief discussion of the emission concentration limits established to screen the cars is presented.

After identifying the test procedures used by the inspection test facility, the discussion includes test and corrective maintenance procedures distributed to participating maintenance centers. The section concludes with a discussion of significant problems and difficulties encountered and resolved during the learning phase.

8.1 VEHICLE SELECTION, SCHEDULING, AND DATA MANAGEMENT

The 120-vehicle test sample lot was derived directly from the larger sample 1200-vehicle distribution, using a 1:10 proportion wherever possible. Based on information provided by R.H. Donneley Corporation as related to California vehicle registrations, projections were made for the total year of 1970. The information indicated that for a population of approximately 8.5 million vehicles applicable to a statewide program, each selected sample would represent roughly 7000 registered vehicles of a given make and model year. Two exceptions to this direct proportionality are worthy of note and were concerned with the sample size of imported cars and also Chrysler Imperials. As noted previously, only Volkswagen, Toyota, and

Datsun would be included as representatives of the P/C-6 class of vehicles. In the case of the Chrysler Imperials, three model years were chosen to represent the total Imperial population, although no one year included sufficient quantity of registration to warrant representation.

Vehicle test scheduling and dispatching were handled somewhat differently from the plan envisioned for the 1200-vehicle main test program. This was necessitated both by lack of firm emission test limits and by the ownership of the 120-test vehicles. Because of the initial constraint that 50 percent of the tested vehicles be rejected based on emission levels, it was necessary to first test all vehicles, evaluate the results, establish the cutoff limits, and identify vehicles requiring corrective actions. Previously derived limits from other studies could not be imposed since the acceptable statistical deviations of such a small sample size as considered here could easily have skewed the representation such that equal distributions would be highly unlikely. Once the acceptance limits were established, the identified vehicles were dispatched to participating maintenance facilities. Different test rates (vehicles per day) were established based on estimated throughput time for a given test regime on an 8-hour work shift. Certificate of Compliance testing processed 12 vehicles on the first assigned test day and 15 on the second assigned day. Idle test regime processed 13 on the first day and 10 on the second day. Key Mode testing accomplished 10 on the initial test date, 7 on the second assigned date, and 8 on the third date. For the Diagnostic testing, the following testing rates occurred on successive days: 5, 8, 9, 5, and 2 (completion day). There were several test days designated as "clean-up" days during which transitional stragglers were processed before initiating a different test regime.

Vehicle dispatching and queueing was controlled through the installation of computer tab cards that identify the vehicle, participant, and applicable test regime. The cards, when placed in a card service rack, also alert test and administrative personnel to the exact status of each vehicle being processed. During the learning phase, vehicle pickup and delivery was limited to interfacing with the participating maintenance centers since the 120 vehicles were supplied by Northrop employees. Thus the vehicles were left at the inspection facility for testing and retrieved when the employee completed his normal work shift. In cases of overnight requirements, the employees were provided with one of five loan cars. No major delays in car delivery and pickup were noted while utilizing the two assigned drivers for the

entire learning phase. The computer tab cards proved adequate in maintaining control and noting vehicle activities.

Data management involved both manual controls and computerized entry and retrieval. All original data related to a particular vehicle was stored in individual file folders. Information included all agreement forms, computer tab cards, emission test results, and maintenance service records. All pertinent data are manually entered on computer coding forms, keypunched to computer format, and entered into the computerized study data base for later retrieval.

8.2 MAINTENANCE FACILITY PARTICIPATION AND COOPERATION

It was expected that the learning phase would reveal areas of program administration and implementation which could be refined for use throughout the main test phase of the current program. On the whole, participating maintenance facilities cooperated satisfactorily in their performance. There were one or two areas, however, in which most service centers did not fulfill stated requirements. All Statements of Work issued to participating maintenance centers call for the return to Northrop of any parts removed from a given test vehicle. In many cases during the learning phase, such parts were not returned as required. A memorandum will be delivered to each service manager as a reminder of this requirement, indicating that during the main test phase, all parts must be returned as required by the purchase orders issued.

A second point of improvement is the nature of service performed. Maintenance centers equipped with advanced automotive diagnostic devices, or "super-tuners" as they are commonly called, are performing service in excess of that prescribed by the emission test schemes under evaluation. Unfamiliarity with the prescribed procedures, uncertainty as to their validity, desire to assure maximum quality in servicing, and concern over maintaining adequate performance apparently have caused maintenance personnel to exercise extra effort in servicing. This deviation from program design will be discussed thoroughly with the service manager of each of the maintenance centers involved and will be corrected prior to implementation of the main test phase.

8.2.1 Certificate of Compliance Maintenance Centers

Because the Certificate of Compliance inspection is a well-defined set of procedures which, in substance, have been required of maintenance centers for many years, no significant difficulties or problems were encountered in implementing this particular test. Little or no specialized learning on the part of maintenance personnel was required by this test and, as expected, it proved to be the simplest to administer.

8.2.2 Idle Test Maintenance Centers

It was the Idle test which required considerable learning and orientation during this preliminary implementation phase. Considering the necessary familiarization and learning involved, it must be concluded that this test and the subsequent repairs were performed quite well. One area that should be improved is the unusually large number of carburetors rebuilt as opposed to adjusted. It is apparent that full use is not being made of carburetor adjustment options. In addition to the probable increased time and cost involved, improper adjustments in transmission linkages were common on cars whose carburetors had been rebuilt. These incorrect adjustments caused the cars in question to operate in a manner unacceptable to their owners. Consequently these vehicles were returned to their respective service centers for corrective maintenance. Complaints included rough idling, improper shifting characteristics, and in cases where the air-to-fuel adjustment was too lean, owners complained of poor starts in cold weather.

8.2.3 Key Mode Test Maintenance

As in the case of the Idle test, maintenance personnel are not taking full advantage of carburetor adjustments in their procedures. More carburetors are being rebuilt than one would expect are necessary. In one particular case, test serial number 1242, prior to service, low cruise CO was measured as 9.72 percent, high cruise as 6.13 percent. After rebuilding the carburetor, low cruise CO dropped insignificantly to 9.71 percent, while high-cruise CO increased to 8.08 percent. It is apparent from the complete service and emission record of this car and of others, that carburetor adjustments as prescribed by the Key Mode Truth Charts are not being used to the full extent they should be.

8.2.4 Diagnostic Test Maintenance Centers

Due both to the high degree of training required for Diagnostic personnel and to the high degree of specificity in the Diagnostic maintenance procedures themselves, many rediagnoses were required for vehicles subjected to the Diagnostic test. It has not yet been precisely determined to what extent each of these two factors contributed to the less-than-optimal performance encountered. The maintenance centers involved have, on the whole, adhered strictly to instructions issued to them in the performance of their work.

8.3 EMISSION LIMITS ADEQUACY

As discussed in paragraph 7.3, greater than a 50 percent failure rate was obtained in some cases. It is therefore necessary to modify the limits used during the learning phase. The recommended emission limits for the 1200-vehicle test program are discussed in paragraph 9.3.

8.4 TEST PROCEDURES DOCUMENTATION

One hundred and twenty vehicles were tested in accordance with the procedures described below. Those vehicles having emissions in excess of the levels determined by Northrop were repaired and/or adjusted until they complied with the prescribed levels, or until Northrop and the Board was convinced that they could not be brought into compliance without major repairs. This phase of the project was conducted as a cooperative effort between Northrop, the personnel responsible for vehicle repair and/or adjustment, and the Air Resources Board staff.

Based upon the findings of this preliminary training phase, some minor modifications to the procedures are recommended before starting the major part of the study.

Documentation related to the vehicle test and maintenance program is divided into two categories: test center inspection facility operating procedures, and the maintenance facility test procedures. For each category, the discussion below includes the proposed procedures, and the updated and revised procedures.

8.4.1 Inspection Facility Operating Procedures

The following paragraphs document a set of operating emission test procedures for the Certificate of Compliance, Idle test, Key Mode, and Diagnostic test progressing from the pre-learning phase (as documented in the Northrop Corporation Study Contract) to the revised and updated learning phase version.

8.4.1.1 Certificate of Complaince

No emission test other than the seven-mode hot start is required.

8.4.1.2 Idle Inspection

It has been shown that an emission inspection at idle has statistical validity in determining whether a vehicle has high or low emissions on the standard seven-mode cycle. The advantage of an Idle inspection is that no dynamometer is required. An Idle inspection program could be implemented by the existing licensed stations. Purchase of the required instruments would cost the licensed station about one-fourth as much as the purchase and installation of a dynamometer and the instruments required for the seven-mode test.

The Idle inspection procedure is as follows. In order to determine the time required for the Idle emission inspection, it is necessary to record the time for the inspection to the nearest second.

a. Original (As Noted in Contract)

(1) Insert probe in tailpipe.

(2) Record emissions of hydrocarbons, carbon monoxide, and oxides of nitrogen, and the vehicle license number. If the emissions are at or below passing limits, withdraw probe and note the time. Proceed to next car. The passing limits suggested are as follows:

	HC (PPM)	CO (%)
Controlled Vehicles	250	4
Uncontrolled Vehicles	700	5

The NO_x limits at 2500 RPM in neutral will be determined from Air Resources Board laboratory data. The above limits are selected to reject approximately one-half of the vehicles tested. About 20 percent of the vehicles would require a more extensive tuneup, such as replacing plugs, points, etc.

(3) If Idle emissions are higher than the passing limits, the vehicle shall be sent to one of the garages participating in this program, and following sequence shall be followed until the Idle emissions are reduced to passing limits. The garage shall be instructed to make normal charges for these adjustments.

b. Modified (As Used During Learning Phase)

(1) Insert probe in tailpipe

(2) Record emissions of HC, CO and NO_x. If the emissions are at or below passing limits, withdraw probe and record time. Proceed to next car. The passing limits for controlled and uncontrolled cars are as follows:

	HC (PPM)	CO (%)
Controlled Cars	250	4
Uncontrolled Cars	700	5

These limits were selected to reject approximately one-half of the vehicles tested. About 20 percent of the vehicles require a more extensive tuneup, such as replacing plugs, points, etc.

(3) If Idle emissions are above passing limits, the vehicle will be sent to one of the garages participating in the program.

(4) After repair, retest for Idle emissions. Return acceptable vehicles, and contact inspection facility for nonpassing vehicles.

8.4.1.3 Key Mode Inspection

a. Original (As Noted in Contract)

(1) Insert probe in tailpipe and accomplish Key Mode inspection according to procedure developed by Clayton Manufacturing Company.

(2) No further operations will be performed on the vehicle if the emissions are below the failure levels set for each of the modes. Otherwise, the vehicle will be sent to a participating garage for the repairs indicated by the Key Mode inspection

Key Mode Test Limits

	Idle	Low Cruise	High Cruise
Controlled Vehicles			
CO (%)	4.0	2.5	2.5
HC (PPM)	350	300	300
Uncontrolled Vehicles			
CO (%)	7.0	3.5	3.5
HC (PPM)	800	550	550

Note: The above limits were developed by Clayton from existing emission data. These limits allow a 50 percent rejection rate.

(3) After the vehicle is returned from the garage, it will be given another Key-Mode test. If it fails the Key-Mode test the second time, Northrop personnel will work with the garage to find the problem which is causing the high emissions.

b. Modifications During Learning Phase - None.

8.4.1.4 Diagnostic Inspection

a. Original (As Noted in Contract)

(1) Insert probe in tailpipe, and connect up oscilloscope diagnostic console.

(2) Operate vehicle at idle, and read the hydrocarbons and carbon monoxide.

(3) Operate vehicle at 60 mph, full throttle (avoid transmission downshift), and read hydrocarbons and carbon monoxide.

(4) Operate vehicle at 50 mph, cruise condition, and read the hydrocarbons, carbon monoxide, and oxides of nitrogen concentration.

(5) Close throttle. Allow vehicle to decelerate from the 50 mph cruise condition and read the hydrocarbon concentration.

Note: Passing emission limits will be set so that approximately 50 percent of the cars tested will require adjustment. Vehicles requiring adjustment will be given a detailed engine diagnosis using the oscilloscope equipment to pinpoint the engine problem as closely as possible. The diagnostician will then write specific instructions to the mechanic for the exact work to be accomplished.

Diagnostic Test Limits

	Idle	60 MPH/ Full Throttle	50-MPH Cruise	Decel
Controlled Vehicles				
HC (PPM)	300	250	250	2000
CO (%)	4.0	5.5	0.25	-
Uncontrolled Vehicles				
HC (PPM)	700	400	550	9000
CO (%)	7.0	5.5	3.5	-

(6) The vehicle will then be sent to the repair facilities for the corrective maintenance indicated by the Diagnostic inspection.

(7) Upon return of the vehicle from the garage, it will be given another Diagnostic inspection.

(8) If the vehicle fails the Diagnostic inspection test the second time, the oscilloscope console will be used to determine whether the original problem had been corrected. The diagnostician and the repair garage will work together to find the problem causing the high emissions.

b. Modifications During Learning Phase - None.

8.4.2 Maintenance Facility Procedures

Following the initial inspection performed by the test personnel, and based on established emission limits, those vehicles requiring corrective actions are dispatched to the selected maintenance facility. Recommended courses of action are delineated on procedures provided by Northrop. Examples of these procedures are included in the following figures. For each of the test regimes, two procedures are included; the first is one stated in the contract, while the second is that used during the learning phase. Examples of forms to be filled out by the participating garages are included with the appropriate figure.

CERTIFICATE OF COMPLIANCE PROCEDURE

1. With engine idling, check the crankcase device:

   a. Device types 1 and 4 - Disconnect the hose connecting the PCV valve to the crankcase and check for vacuum.

   b. Device type 2 - Remove oil filler cap and check for crackcase vacuum.

   c. Device type 3 - No vacuum check necessary.

2. Check for free flow through other components of the device, such as hoses, flame arrester and filter.

3. Determine that there are no misfires within the ignition system (the use of a scope is recommended).

4. Check the carburetor choke and adjust, if necessary, to open fully at normal engine operating temperature.

5. Check the ignition timing and point dwell; adjust if necessary to the manufacturer's specifications. For certification purposes adjustment is required only when the timing is advanced more than 3 degrees from manufacturer's recommended setting.

6. If the vehicle is equipped with an air pump, disconnect the hose from the pump outlet and check for adequate air flow. If the air pump is not functioning, it should be replaced.

7. Measure the air-to-fuel ratio (A/F) and adjust, if necessary to the manufacturer's specifications. Air injection engines shall be adjusted with the air pump outlet hose disconnected. Avoid side-to-side unbalance, or lean misfires.

8. Measure Idle RPM and adjust, if necessary, to a speed no slower than manufacturer's specifications.

9. Re-install the carburetor air cleaner and recheck the A/F ratio and Idle RPM. A/F ratio and Idle RPM shall meet specifications with the air cleaner installed.

10. Assure free operation of manifold heat riser valve, if the vehicle is so equipped.

Figure 8-1. Certificate of Compliance Procedure
(Original - As Noted in Contract)

CERTIFICATE OF COMPLIANCE PROCEDURE

FOR

PARTICIPATING GARAGES

A. PROCEDURES

1. Perform the existing "Certificate of Compliance" inspection and repair per HPH 82.1, "Handbook for Installation and Inspection Stations."

2. When vehicle is ready for certification, complete necessary certificate and/or forms and return one (1) copy to Northrop Corporation. Name and address will be Northrop Corporation.

3. If no certification can be achieved, describe reasons why.

B. EXCEPTIONS

1. If an emission control device is physically missing from the vehicle, DO NOT install a new one; however, perform as much of the Certificate of Compliance as possible, as indicated in Item A above.

Figure 8-2. Certificate of Compliance Procedure
(Modified - As Used in Learning Phase)

IDLE TEST/REPAIR PROCEDURE

a. Insert probe in tailpipe and monitor hydrocarbons, and carbon monoxide (CO) emissions during adjustments.

b. With engine idling, disconnect PCV valve from crankcase and check for vacuum.

c. Remove air cleaner. Put transmission in drive range if automatic. Lean out Idle mixture to a CO value between 1.0% and 2.0%. Avoid a rough idle, side-to-side unbalance or rise in hydrocarbons indicating misfire.

d. If CO or hydrocarbons remain over limit, connect a tachometer and readjust the idle speed to a speed no slower than factory specifications.

e. If CO remains over the passing limit, a carburetor malfunction is indicated. Repair as required.

f. If hydrocarbons at Idle (with the transmission in neutral) remain over limits, connect a timing light and retard the spark to specification. Re-adjust the Idle speed to specification.

g. If hydrocarbons remain over the passing limits, diagnose the engine with an oscilloscope console and accomplish the indicated repairs.

h. After repair retest for Idle emissions.

i. If the Idle emission passing limits are achieved, return the vehicle to the Air Resources Board for a seven-mode test.

j. If Idle passing limits are not met after the repair during the 120-car preliminary training phase, the Air Resources Board representative should be contacted.

Figure 8-3. Idle Test/Repair Procedure
(Original - As Noted in Contract)

IDLE EMISSION TEST, ADJUSTMENT, AND REPAIR PROCEDURE

FOR

PARTICIPATING GARAGES

The following test, adjustment, and repair procedure is recommended to bring the vehicle within prescribed emission levels. Only those adjustments or repair actions required to correct Idle emissions are to be accomplished. Use attached data sheet to record emission measurements.

A. PRE-TEST

Prepare vehicle and equipment for test.

1. Test Equipment - Service, warm-up, and calibrate Sun HC/CO test equipment per manufacturer's specifications.

2. Test Vehicle - Verify engine is at normal operating temperature (warm-up as required).

3. Hook-Up - Insert probe in exhaust pipe (driver side if dual exhaust), hook-up tachometer per manufacturer's instructions.

B. TEST

Perform HC/CO and RPM measurements and compare to Idle Test Standards.

1. 2500 RPM - Operate engine in neutral at 2500 RPM, record HC/CO.

2. Idle RPM - Operate engine at Idle RPM (in drive if automatic transmission), record measurements.

3. Compare - Idle RPM emissions to test standards and record manufacturer's specified RPM; if HC or CO is high, adjust per Step C. If HC and CO are within limits return vehicle to Northrop.

C. ADJUST

Perform engine adjustments for HC/CO.

Note: When any adjustment step brings emissions within limits STOP procedure at that point and re-test per Step B.

Figure 8-4. Idle Test/Repair Procedure
(Modified - As Used in Learning Phase) (Sheet 1 of 4)

Adjustment Procedure

1. RPM - Adjust (if required) to manufacturer's specifications; recheck HC and CO and record.

2. HC - Check timing per manufacturer's procedure and record. If timing is not at manufacturer's specification, adjust as required; re-adjust RPM, if required; re-check HC/CO and record.

3. CO

   (a) Adjust Idle mixture to manufacturer's specification. Where no specifications are available use: 2.0 to 5.0% CO for uncontrolled vehicles and 1.0 to 4.0% CO for controlled vehicles. Re-adjust RPM, if required.

   Note: When adjusting Idle CO, attempt to reduce CO to lowest possible value, consistent with good Idle quality. Avoid a rough Idle condition, side to side unbalance or increase in HC (HC increase indicates a lean idle misfire).

   If CO/HC emissions cannot be reduced to within limits, while maintaining acceptable Idle quality; diagnose and repair (Step D) vehicle as required. ONLY those repairs necessary to bring Idle HC/CO within limits are to be accomplished.

   (b) After adjustment, enrichen mixture slightly to avoid too lean a condition. Recheck HC/CO and record.

D. REPAIR

Diagnose and repair engine; when repair is complete re-test per Step B.

1. Diagnose Engine.

2. Repair malfunction per manufacturer's specifications.

3. Retest per Step B, record measurements.

4. If emission limits cannot be achieved within the reapir constraints imposed by Northrop, contact Northrop immediately for disposition.

Figure 8-4. Idle Test/Repair Procedure
(Modified - As Used in Learning Phase) (Sheet 2 of 4)

HELPFUL HINTS

High HC - Indications are caused by ignition misfires, advanced ignition timing, exhaust valve leakage, and over-lean mixtures. Ignition misfires can be diagnosed by use of the oscilloscope. Timing problems by use of timing light. Valve failure is indicated by cylinder balance testing with compression test verification. Lean misfire is caused by too lean Idle mixture setting or manifold vacuum leaks.

High CO - Can be caused by abnormally restricted air cleaner, stuck or partially closed choke or carburetor Idle circuit failure. Rough or erratic Idle can be caused by PCV valve malfunction. Idle HC/CO failure/malfunction Truth Table can be used as a guide to identifying failures.

MALFUNCTION TRUTH TABLE

Malfunction	HC		CO		Rough Idle
	High	Very High	High	Very High	
PCV Valve Dirty/ Restricted			X		X
Air Cleaner Dirty/ Restricted			X	X	
Choke Stuck Partially Closed				X	
Carburetor Idle Circuit Malfunction	X		X		X
Intake Manifold Leak	X	X			X
Ignition Timing Advanced	X				
Leaky Exhaust Valves	X	X			X
Ignition System Misfire	X	X			X

Figure 8-4. Idle Test/Repair Procedure
(Modified - As Used in Learning Phase) (Sheet 3 of 4)

IDLE INSPECTION DATA SHEET

Car Number: 1297 License Number: KAE 058 Test Date: 12/22/70

TEST

1. RPM 2500; HC 1800 ppm; CO 2.5 %
2. RPM 900 ; HC 1300 ppm; CO 7.5 %
3. RPM 550 Mfg. Spec.; HC 700ppm max.; CO 5.0%max. (Uncontrolled Standard)

~~HC 250ppm max.; CO 4.0%max. (Controlled Standard)~~

ADJUST

1. (Idle Speed) RPM 550 0 to + 50; HC 1200 ppm; CO 5.7 %
2. (Timing) Mfg. Spec. 8 °TDC; Engine Timing 12 °TDC
   RPM 550 ; HC 975 ppm; CO 7.5 %
3. (CO) RPM 2500 ; HC 900 ppm; CO 6 %

REPAIR

3. RPM: 550 ; HC 650 ppm; CO 4.5 %

REMARKS: This car is suffering from very poor maintenance. After major tune-up, car went into specs, however after prolonged idle period hydrocarbon and CO increase. Suggest customer drive car period of time and recheck later to see if carbon that is holding rings to pistons dissipates

Cone Chevrolet

Figure 8-4. Idle Test/Repair Procedure
(Modified - As Used in Learning Phase) (Sheet 4 of 4)

CLAYTON KEY MODE EMISSION TEST

REPAIR PROCEDURE

FOR

PARTICIPATING GARAGES

No formal procedure was outlined in the contract. The following was developed for use during the learning phase.

1. An emission test report card will accompany each vehicle which requires adjustment and/or repair. A sample report card is attached.

2. This report card will be used in conjunction with the Key mode TRUTH CHARTS instruction book published by Clayton.

3. The corresponding truth chart (found in the instruction book) will be used to assist in diagnosing the problem. Only those repairs suggested should be performed.

4. After repair, the suggested adjustments (timing, speed, and carburetor) will be made before returning vehicle to Northrop. Record results on attached data sheet.

Figure 8-5. Key Mode Emission Test/Repair Procedure
(Sheet 1 of 2)

KEY MODE REPORT CARD

CONTROLLED ☐

CAR NUMBER 1279 YEAR 58

UNCONTROLLED ☑

	IDLE	LOW CRUISE	HIGH CRUISE
- CO - CARBON MONOXIDE	6.48 ✓	4.56 ✓	3.39 ✓
- HC - UNBURNED HYDROCARBON	353	381	293

✓ = REJECT

After final repair or adjustment, insure that the following adjustments are within manufacturer's specification.

Idle Speed_____ RPM; Timing_____ °TDC; Carburetion_____ A/FR

REMARKS: _____

Figure 8-5. Key Mode Emission Test/Repair Procedure
(Sheet 2 of 2)

DIAGNOSTIC TEST

ADJUSTMENT AND REPAIR PROCEDURE

No formal procedure was outlined in the contract. The following was developed for use during the learning phase.

1. A Diagnostic analysis report will accompany each vehicle which requires adjustment and/or repair. A sample Diagnostic analysis report is attached.

2. ONLY those adjustments and repairs indicated under REPAIR INSTRUCTIONS are to be performed.

3. The Diagnostic analysis report is included for information purposes only with checks for satisfactory and unsatisfactory on those functions performed.

4. If repairs other than those requested are apparent, please indicate your recommendations under REMARKS. Keep in mind that only those repairs will be performed that are needed to bring exhaust emissions within an acceptable range.

5. If failure occurs on retest, the cars will be given additional diagnosis and returned for further repair work.

Figure 8-6. Diagnostic Test/Repair Procedure
(Sheet 1 of 2)

DIAGNOSTIC ANALYSIS REPORT

	S	U	Function
1	✓		Air Cleaner
2	—		Heat Riser
3	✓		Carb. Choke Action
4	✓		Rhythm Test
5	✓		PCV Valve Action
6			Air Injection Pump
7			Air Injection Check Valves
8			Gulp Valve
9	✓		Emission System Hose Cond.
10	✓		Polarity
11	✓		Cap
12	✓		Rotor
13	✓		Condenser
14	✓		Coil
15	✓		Idle Speed Spec 850 Actual 860
16	✓		Dwell Spec 50° Actual 54°
17	✓		Timing (Vac Hose Off) Spec TDC Actual TDC
18		✓	Mechanical Advance (Vac Hose Off) Spec 14° @ 2600 Actual 21°
19		✓	Total Advance (Vac Hose On) Spec 19° Actual 31°
20		✓	Vacuum Advance (Total-Mech Advance) Spec 5° @ 2" Actual 10°
21	✓		Firing Order 1 4 3 2 — — — — Power Drop Test (5 Sec per Cycle) 13 13 15 13 — — — —
22	✓		Plug Condition-Idle
23		✓	Carb - Idle AFR _____ CO 5.6
24	✓		Plug Condition - Loaded
25		✓	Carb - Power AFR _____ CO 4.8
26	✓		Plug Wires
27	✓		Points
28	✓		Detonation
29			Carb - Cruise AFR _____ CO _____
30	✓		Carb Surges
31			Blow - By
32	✓		Valve Action
33	✓		Knocks
34	✓		Head Gasket (On decel - use Bloc Chek)

Car Number 1205

License Number ZZG 123

Date 1/18/71

Test Start Time 1300

	S	U	Visual Check
35	✓		Battery Appearance
36	✓		Cables
37		✓	Belts Gen Belt Loose
38	✓		Hoses
39	—		Radiator
40	✓		Oil Leaks
41	✓		Fuel Leaks

42 REPAIR INSTRUCTIONS - Use normal operating procedure, itemize repair actions on invoice, return all parts that are replaced.

Reset Points, Timing
Adjust Fuel Injectors
(Idle too rich)

Check Distributor Advance Curve and correct if necessary

Test Completion Time 1400

REMARKS

Dwell adjusted
Timing Reset
Fuel Pressure Checked and adjusted
Idle Reset

NOTE: Remove and replace radiator cap above 2000 RPM

Figure 8-6. Diagnostic Test/Repair Procedure (Sheet 2 of 2)

8.5 DIFFICULTIES ENCOUNTERED

During the short period of the learning phase, few problems were encountered with participating maintenance facilities. Categorically, it can be stated that the difficulties could be broadly described as not pursuing a course of action to the fullest extent or conversely going beyond the scope of anticipated effort. In the former case, corrections are achieved by returning the vehicles to the appropriate service center. This did affect the vehicle dispatching and cause some minor inconvenience to vehicle owners. When maintenance facilities performed more servicing than desired, this increased the cost of maintenance without materially affecting emission changes. Listed below are some of the problems dealt with during this initial phase.

a. Improper adjustment of transmission linkages was evident in maintenance involving rebuilt carburetors in at least three cases.

b. Garages involved in Idle, Key Mode, and Diagnostic testing failed to make full use of carburetor adjustment options in many cases.

c. Service was performed in excess of that required by the applicable test scheme and as provided for in the procedures. There were at least six cases included in this category.

d. Carburetion adjustments were so lean in at least four cases that vehicle owners complained of the vehicle's poor operation or of its inability to start and stay running when engine temperature was below normal operating temperature.

e. Original replaced parts were not returned with test vehicles in many cases when replacements occurred.

f. Inexperience of Diagnostic personnel at the inspection facility resulted in vehicle throughput rate lower than estimated causing rescheduling of vehicles.

SECTION 9
RECOMMENDED TEST PHASE MODIFICATIONS

Based on the findings and results of the learning phase, minor modifications and changes are recommended for implementation during the subsequent 1200-vehicle main test phase of this pilot study. When implemented these alterations will strengthen the testing effort where weakness was evident. Where policies and procedures were marginally adequate, minor revisions will enhance the remaining portion of the study. Presented below are recommendations that affect the following subject areas: vehicle selection, scheduling, and data management; test regimes and procedures; emission limits; and maintenance facilities and policies.

9.1 VEHICLE SELECTION, SCHEDULING, AND DATA MANAGEMENT

The vehicle selection procedure was defined to satisfy the experiment design and therefore no recommendations for change will be made.

Vehicle scheduling will be performed by the algorithm defined in Section 3. There is no reason to believe that this method will require modification during the main test program. A list of participant's names and test dates will be available on Wednesday prior to the test date. This list will be used to confirm availability of the vehicle when required. If the vehicle is not available, another will be substituted and the unavailable vehicle will be rescheduled.

Data Management will be computerized for the main testing program and the data capturing procedures may be changed slightly from time to time to increase efficiency. The recommendations of section 9.4, if implemented, will increase the quality of the data captured.

9.2 TEST REQUIREMENTS AND PROCEDURES

The following changes to the learning phase test/repair procedures are recommended for the 1200-vehicle test program.

9.2.1 Certificate of Compliance

To achieve a greater emission reduction at an apparent nominal cost increase, it is recommended that basic Idle adjustment of speed, carburetor, and ignition timing to manufacturer's specifications be made to all uncontrolled vehicles. The procedure adopted under current Certificate of Compliance requires only a crankcase emission control device inspection be performed for uncontrolled vehicles. The recommended change is as follows:

a. Measure Idle RPM and adjust, if necessary, to a speed no slower than manufacturer's specifications.

b. Measure the ignition timing and point dwell; adjust if necessary to manufacturer's specifications. For certification purposes, adjustment is required only when the timing is advanced more than three (3) degrees from manufacturer's recommended setting.

c. Measure the air-to-fuel ratio (A/F) and adjust, if necessary to 12.5 to 13.5 on uncontrolled vehicles.

9.2.2 Idle Test Procedure

No change to the learning phase procedure is recommended.

9.2.3 Key Mode Test Procedure

Clayton Manufacturing recommends that a full throttle test be made in conjunction with the normal Key Mode test, but that rejection and repairs be based on the three Key Mode test results. Clayton feels that a meaningful inspection procedure should

reasonably insure that a vehicle, which has been determined to have an acceptable level of emissions, will not develop a malfunction and become a high emitter within the next few miles of operation.

Because the program includes the recall of vehicles for re-inspection approximately six months after the original inspection, they feel it is very important that the full throttle information be obtained at the time of the original Key Mode test. This is to establish the predictability of vehicle malfunctions developing based on degradation exposed at full throttle only. They do not advocate, at this time, doing any repairs based solely on a full throttle rejection, and suggest that the data only be recorded for study.

Northrop agrees to Clayton's recommendations, however this change constitutes a change in scope and will have to be negotiated with the ARB if implemented. There is a risk factor which must be considered for the older vehicles when subjected to a full-load condition both in the engine and power train which could result in added repair costs to the State.

9.2.4 Diagnostic Test Procedure

The Diagnostic test procedure for engine diagnosis will basically remain as performed in the learning phase. Total engine Diagnosis will be performed. The engine Diagnosis performed by test facility personnel and the resulting repair recommendations do not make adequate use of the emission data during diagnosis. It is recommended that the diagnosticians be given additional specific instruction on how to use the emission data for diagnosis.

The functions to be performed during Diagnostic analysis (see Figure 8-6) should be arranged so that the two-man Diagnostic team can work in parallel. Figure 9-1 is the recommended order in which the functions should be accomplished.

However, emission data will be used for generating specific repair action as it relates to the failed modes of the test cycle. It is felt at this time that streamlining of the procedure will be developed as the program proceeds.

Time		Man A	Man B
Phase I	(		Car Number
	(	Steps 35-41	Lic. Number
	(	Steps 1-9	Date
	(		Test Start Time
	(		Steps 15-21 (Spec Only)
Phase II	(	Hook-up	
	(	Steps 10-14	
Phase III	(	Steps 15-34 (Jointly)	
Phase IV	(	Disconnect	Step 42

Figure 9-1. Order of Performance for Diagnostic Analysis

9.2.5 Test-Vehicle Retesting

Current procedures call for retest of only those cars that are serviced (i.e. one-half of Idle, Key Mode, Diagnostic, and all Certificate of Compliance test vehicles). As indicated in the discussion of the experiment design (Section 3), no means are provided to determine the consistency of data obtained by test equipment and procedures. In the present configuration, there is no statistically valid means of assuring that quoted reductions in emissions are accurate because there is no test of equipment reliability. After receiving one seven-mode test, would identical levels be recorded for the same car six-hours later even if no service were performed? It is assumed so but this cannot be proved without data. Valid experiments require a control group. As is, this experiment has none. If as few as 30-50 cars that passed emission limits and received no service were retested, a valid figure for average emission reduction could be determined. It is recommended that 50 cars which receive no service be subjected to a second 7-mode test at some interval to be determined after it is tested initially. From this control group, equipment and personnel reliability, system error, the contribution of individual driver error, and much vital information will be determined. While the cost would be nominal, the

benefits would be immeasurably valuable. If the ARB wishes to implement this recommendation, negotiations should commence immediately, as this effort should begin with commencement of the main test phase, and it is now out of scope of the present contract.

9.3 EMISSION LIMITS

Emission limits used for the Idle, Key Mode, and Diagnostic tests during the learning phase resulted in some minor modification of limits proposed for the main 1200-vehicle test program (Figure 9-2) in order to achieve a 50/50 pass/fail criteria. The changes are discussed below.

9.3.1 Idle Test Limits

It is felt that the limits used in the learning phase are too stringent in the areas of controlled HC and uncontrolled CO. It is recommended that the HC limit for controlled cars be increased to 300ppm and the CO limit for uncontrolled cars be increased to 6.0%. These limits would have resulted in seven controlled and seven uncontrolled failures with two controlled and three uncontrolled cars marginal in the learning phase.

9.3.2 Key Mode Test Limits

A substantial number of uncontrolled vehicles would have been rejected if the limits developed would have been used. It is recommended that the uncontrolled carbon monoxide limit at low cruise be changed from 3.5 to 4.5%. This increased value was proposed by Clayton after final results were reviewed from the Key Mode test data.

9.3.3 Diagnostic Test Limits

The Diagnostic test limits developed for use in the learning phase include a limit for carbon monoxide in the full-throttle 60 mph mode for both controlled and uncontrolled vehicles. For this mode, the carburetor is in the power enrichening circuit and depending upon carburetor design and type, wide varying values of CO

Idle Test Limits

Controlled	HC 300 ppm	CO 4%	No_x____
Uncontrolled	HC 700 ppm	CO 6%	No_x____

Key-Mode Test Limits

Controlled	Idle	Lo Cruise	Hi Cruise
CO	4.0	2.5	2.5
HO	350	300	300
Uncontrolled			
CO	7.0	4.5	3.5
HC	800	550	550

Diagnostic Test Limits

Controlled	Idle	60/Loaded	50/8hp	Decel
HC	300	250	250	2000
CO	4.0	-	2.5	-
Uncontrolled				
HC	700	400	550	9000
CO	7.0	-	3.5	-

Figure 9-2. Recommended Test Limits

may be encountered. In addition, no additional Diagnostic information is obtained over the other modes checked. It is therefore recommended that no single value or limit be used for rejection purposes if only this mode exceeds the CO emission limit.

9.4 MAINTENANCE FACILITIES AND POLICIES

The main problem common to all test types is the lack of traceability to the specific repair performed. Even when replaced parts were returned, additional parts were indicated on the invoice. The two recommendations below should alleviate these problems.

1. Each garage should be supplied with a memorandum reminding them that the purchase order requires the return of all replaced non-exchange parts to Northrop.

2. In addition, it is recommended that the appropriate check-sheets, Figures 9-3 through 9-5, accompany each vehicle to be serviced and that they be returned after service.

The Idle and Key Mode service performed showed that more service was being performed than was required to reduce emissions to an acceptable point. Attempts were made, particularly by those shops better equipped than average, to achieve lowest possible emission levels. It is recommended that the memorandum, (1) above, remind the garages that only that work be performed that is necessary to achieve acceptable emission levels, not to attain lowest possible emission levels. It is also recommended that those few garages habitually failing in this area be contacted personally.

Vehicle No._____ Ignition

PLUGS	REPLACED	☐	GAP & CLEAN	☐
POINTS	REPLACED	☐		
CONDENSER	REPLACED	☐		
DISTRIBUTOR CAP	REPLACED	☐		
ROTOR	REPLACED	☐		
SECONDARY WIRES	REPLACED	☐		
VACUUM ADVANCE	REPLACED	☐		
BALLAST RESISTOR	REPLACED	☐		
BATTERY VOLTAGE	LOW	☐	HIGH	☐
CHARGING VOLTAGE	LOW	☐	HIGH	☐

DWELL AS RECEIVED _____ ADJUSTED TO _____

BASIC TIMING AS RECEIVED _____ ADJUSTED TO _____

COMMENTS

Figure 9-3. California Vehicle Emission Study
Maintenance Check List

Vehicle No._____ Carburetion

	Repaired	Rebuilt	Replaced	New Rebuilt	
CARBURETOR	Type_____	Model_____	BBL's_____	TAG NO._____	
CARBURETOR ADJUSTMENT PERFORMED					
CHOKE		STUCK OPEN	☐	STUCK CLOSED	☐
IDLE SETTINGS		UNBALANCED	☐		
FLOAT		LEAKS	☐	BENT	☐
PRIMARY	Level	LOW	☐	HIGH	☐
	Drop	LOW	☐	HIGH	☐
SECONDARY	Level	LOW	☐	HIGH	☐
	DROP	LOW	☐	HIGH	☐
ACCELERATOR PUMP		MALFUNCTIONING	☐		
JETS		WORN	☐		
METERING RODS		WORN	☐	STUCK	☐
POWER ENRICHENING VALVE		MALFUNCTIONING	☐		
FUEL & VACUUM PASSAGES		PLUGGED	☐		
AIR CLEANER		REPLACED	☐	CLEANED	☐
HEAT RISER VALVE		MALFUNCTIONING	☐	STUCK	☐
CHOKE STOVE		MALFUNCTIONING	☐		
EXHAUST AIR PUMP		MALFUNCTIONING	☐		

COMMENTS

Figure 9-4. California Vehicle Emission Study
Maintenance Check List

Vehicle No._____ Mechanical

VALVES	BURNED	☐	STICKING	☐
VALVE ADJUSTMENT	UNSATISFACTORY	☐	CORRECTED	☐
RINGS	WORN	☐		
VACUUM CONNECTIONS	LEAKING	☐	CORRECTED	☐
GASKETS	LEAKING	☐	CORRECTED	☐
WARM AIR VALVE	MALFUNCTIONING	☐	CORRECTED	☐
COMPRESSION OR CYLINDER BALANCING	UNSATISFACTORY	☐		

CYLINDER NUMBER	COMPRESSION READING	CYLINDER BALANCING RPM DROP
1	_____	_____
2	_____	_____
3	_____	_____
4	_____	_____
5	_____	_____
6	_____	_____
7	_____	_____
8	_____	_____

COMMENTS

_____

_____

_____

Figure 9-5. California Vehicle Emission Study
Maintenance Check List